Biomedical Areas of Strength in Western Sweden

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Executive summary

The present study has been carried out on behalf of GöteborgBIO’s board and aims to provide information that GöteborgBIO needs for its planning of the coming 3.5-year period (2012-2015). The background is that GöteborgBIO, besides its general support of the life science sector in Western Sweden, has one profile area, viz., Biomaterials and Cell Therapy. The question has been raised whether GöteborgBIO should give special support also to other regional areas of strength. To provide the board with information about possible, future profile areas five selected areas have been scrutinized: Biomaterials and Cell Therapy, Vaccines, Medical Signal Processing and Visualisation, Neurological Diseases, and Cardiovascular and Metabolic Diseases. The study analyses five aspects of regional strength: industrial activity, academic scientific strength, clinical practice, regional support schemes, and regional networks and collaborations.

The mapping of each targeted area is based on written documentation as well as on interviews. In total more than 80 interviews were carried out with company representatives, academic research leaders, and policy makers. In analysing the industrial activity regional firms in each area were identified and key data was collected for these firms as well as for firms situated in other parts of Sweden. To map the scientific strength bibliometric analysis of identified research groups was used as one of several tools. We also gathered information about external grants and their development over time. The clinical practice was analysed in less detail than industry and academic research. Besides interview data on the quality of the region’s healthcare services some data on the amount of clinical studies has been collected. The mapping of regional support schemes builds on a combination of documents and interviews. The same applies to our mapping of current networks of collaborative relationships within the region.

Based on the analysis we conclude that all five areas investigated have certain strengths, but these vary in character and magnitude and give varying potential for industrial development and economic growth. The main conclusions, regarding each area’s development potential, can be summarised as follows:

Biomaterials and Cell Therapy:
- Further development of existing cluster
- Linking of biomaterials and cell therapy

Vaccines:
- No basis for cluster formation
- Maintain research strength in current niche
- Opportunity to commercialise research through licensing/start-ups

Medical Signal Processing and Visualisation:
- Potential for research-based industrial development
- Opportunity to use the new Imaging and Intervention Centre for innovation procurement and industrial development
- Opportunity to benefit from development in other (non-medical) application fields

Neurological Diseases:
- No basis for cluster formation
- Potential for more university spin-offs
Cardiovascular and Metabolic Diseases:
• Potential for more university spin-offs
• Further strengthening of dominant firm (AstraZeneca)
• Re-establishment of clinical collaboration between AstraZeneca and the healthcare system
• Potential for corporate spin-offs
• Potential to start cluster-building process
• Potential to strengthen the academic research

It is not our task in this report to suggest what policy that regional actors should adopt in each area. Instead, it is the responsibility of the policy actors to develop and implement their strategies on the basis of the results from this study and other input and considerations. Nonetheless, we would like to bring out the obvious strength of two areas, namely, Biomaterials and Cell Therapy and Cardiovascular and Metabolic Diseases. They are strong both from an academic and industrial point of view and they also receive a great deal of support from regional policy actors. In our opinion they must be seen as strong candidates to be selected as profile areas for GöteborgBIO.

The area of Medical Signal Processing and Visualisation does not exhibit the same strength and is therefore not an obvious candidate. However, there are certain reasons why this area should be considered. Several regional policy actors already support the area and regard it to be important to the future development of the healthcare system. Furthermore, there seem to be good opportunities to link the area to other regional activities – in academia, industry, and healthcare – and this can be expected to have positive effects on the development. One possibility, to make the area more attractive, is to broaden its definition – compared to how this is done in the present study – and include, for example, other IT- and electronics-related activities of relevance to healthcare applications.

As to Vaccines and Neurological Diseases, it is harder to see why they should be selected as profile areas in their own right. Both have certain strengths. At the same time, there are also significant weaknesses, not least with regard to the existing industrial base. Under all circumstances, these areas can be supported through the general support schemes used by GöteborgBIO. In addition, there is an overlap between areas that Vaccines and Neurological Diseases can benefit from. It means that certain projects or companies may receive support dedicated to other areas of strength.

In the final chapter, the report outlines some general conclusions and recommendations. First, it is suggested that for each area of strength the key actors should come together and develop a regional strategy. Second, in some of the areas, especially Biomaterials and Cell Therapy, there is a possibility for the region to take the lead in developing a national strategy. Third, existing regional networks and collaboration patterns should be retained and strengthened. Fourth, the region should try to attract more leading scientists from other parts of Sweden and from abroad. It is also important to secure succession of scientific leadership within each area. Fifth, support of the early phases of commercialisation is important and should be continued.
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1 Introduction

Aim
This report investigates five areas of strength in the biomedical sector of the region of Western Sweden. As based on the analysis it discusses how these areas may further grow and reach their full potential. The selected areas for analysis are:

- Biomaterials and Cell Therapy
- Vaccines
- Medical Signal Processing and Visualisation
- Neurological Diseases
- Cardiovascular and Metabolic Diseases

We have not analysed all possible areas of regional strength within biomedicine. Even so, the five selected areas represent two thirds of the region’s industrial employment within biomedicine, indicating that the report captures some of the industrially most important sub-sectors.

The delimitation of the areas merits a comment. The areas targeted in this report are defined according to somewhat different logics. Two of them, Neurological Diseases and Cardiovascular and Metabolic Diseases, represent disease areas, while the other three are defined based on science and technology. The aim is not to claim that the selected delimitation of the five areas is the only possible one. Instead, this is one approach to understanding how the region’s biomedical sector may be divided into sub-sets, and how these may expand and be successful. This means that there is certain overlap between the areas, for example, with regard to research activities and companies.¹

Background
The report is written on behalf of GöteborgBIO. This is a regional initiative to create a solid base for long-term growth, in the biomedical field within the region, by cultivating academic research and commercial innovations and adaptations within the healthcare system.² GöteborgBIO supports the regional biomedically-related actors and activities broadly, for example, by financing an incubator (at Sahlgrenska Science Park), needs-driven research and methods development, and a school of entrepreneurship. It also supplies verification grants, conducts seminars and various communications and brand-building activities, and not least supports networking activities aimed to link regional actors to one another or to relevant national or foreign partners. To date, GöteborgBIO has, in addition to its general broad-reaching activities, supported two selected profile areas. Firstly, Biomaterials and Cell Therapy is a field with regional strength both industrially and academically, where much of GöteborgBIO’s activities have been focused over the years.³ Secondly, during its initial period (2005-2008)⁴ the area of Cardiovascular and Metabolic Diseases was also in focus, and a methodology to

¹ Besides these areas there may be other biomedical fields that are or have a potential to develop into areas of strength. It can be, for example, new research areas or healthcare specialties where the region has a nationally leading position, but a non-existing industrial base. We have used the interviews as a means to identify such potential areas. However, to verify their potential and map the actors, further data collection will be necessary.
² The underlying project is called ‘Biomedical Development in Western Sweden: a New Innovation System’ (BMV). BMV, more broadly known under its brand name GöteborgBIO (see www.goteborgbio.se), is a ten-year regional development project running from 2005 to 2015 and is financed by Vinnova and a group of regional actors from the public and private sectors. These are Business Region Göteborg, Region Västra Götaland, University of Gothenburg, Chalmers University of Technology, AstraZeneca, Mölnlycke Health Care and Nobel Biocare.
³ GöteborgBIO has limited resources and has therefore chosen to focus its efforts on specific “profile areas”. Other policy actors may have selected other profile or focus areas, for example, related to healthcare.
⁴ Vinnova’s 10-year support of BMV (and other Vinnväxt initiatives) is divided into three planning periods, each one lasting
support early-phase innovation projects through verification grants was successfully developed for this area. The activities were subsequently transferred to Sahlgrenska Science Park, and are now part of the verification support directed at the entire biomedical field. Thus, during the second period (2008-2011) the Cardiovascular and Metabolic Diseases area was not a profile area for GöteborgBIO.

In preparation for the third period (2012-2015) GöteborgBIO aims to identify additional areas of strength where the region has opportunities to develop a flourishing industry, potentially with linkages to universities and healthcare organisations. The report at hand consists of a mapping of five such potential areas of strength (including the present one). We draw conclusions on the development potential for each area and give general recommendations. However, it is up to the regional policy actors to design detailed strategies for how the areas should be supported in order to thrive.5

Structure of the report
The report is structured in the following way. Chapter 2 describes what we have analysed and how it was done in terms of data sources and measures. We then give an overview of the biomedical sector in the region, before we move on to scrutinise each of the aspects of regional strength in chapters 4-8: industrial activity, academic scientific strength, clinical practice, regional support schemes, and regional networks and collaborations. The two last chapters discuss the development potential in each of the fields and draw some general conclusions.

2 What we have analysed and how it was done
Aspects of regional strength
For the region of Western Sweden – that is basically what is equivalent to Region Västra Götaland and the County of Halland – we in this report analyse five aspects of regional strength: industrial activity, academic scientific strength, clinical practice, regional support schemes, and regional networks and collaborations. Not all these aspects need to be equally strong for the area to be considered a regional hotbed. Nevertheless, they are all helpful in creating a blooming sector, and often several of the dimensions intertwine and reinforce one another. Furthermore, there is no linearity or priority between the aspects, meaning that there is not a preferred timeline in developing new areas where some aspect (for example a strong academic research base) should be fulfilled before others.

A first aspect is industrial strength, in the form of existing companies working in the field. Indicators of strength are, for example, many firms, high turnover, a large number of employees and good global market positions. Moreover, the relatedness between these firms in terms of knowledge areas, products or markets is important, where a cluster formation and a critical mass of inter-linked firms is a positive sign for the region. Of importance is also to what extent the companies have relationships with other types of regional, national and global actors.

A second dimension is academic scientific strength. Much of the biomedical industry is science-based, that is, new products, methods and services are not seldom based on results from academic

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3-3½ years. The first two periods are evaluated by international panels before Vinnova takes decision on continued support.

5 The areas to be covered by the study were chosen jointly by the board and the operative management of GöteborgBIO. An important criterion for selection was that the area, besides the presence of academic research, should have an expected potential for industrial development (given that GöteborgBIO is an industry-political initiative).
or corporate research. A strong research base in the region (at firms, universities, hospitals or institutes), thus creates favourable conditions to develop new solutions for patients, and to start new companies and develop incumbent ones that commercialise results (research findings and other knowledge and resources) sprung out from such universities, research institutes, hospitals or firms. In this report we focus only on the academic scientific strength.

A third feature is the region’s clinical practice. This entails the presence and amount of clinicians focusing on each specific area as well as the volume of clinical studies performed and the experience of firms’ access to clinical resources and competencies within the region.

Fourth, regional policy support is often important for an area to flourish. The question here is to what extent the focal strength areas are specifically prioritised and what kind of policy measures that are directed towards these areas.

Finally, in order to understand to what extent the actors are interconnected and exchange personnel, knowledge or other resources current regional networks and collaborations were mapped. One indicator of knowledge exchange and learning is the extent to which regional actors relate to one another, exchange resources or collaborate. A dense regional network may point to ongoing resource mobility and learning processes.

**Data sources**

The mapping and analysis of each targeted area is based on written documentation about firms, academic research groups, clinical activities and support measurements, and we have used the organisations’ own documentation as well as independent reports. Moreover, we lean on 84 interviews with various actors (see Appendix A). Most interviews are related to specific strength areas and made with research leaders and company representatives. Other interviews, for example with representatives of policy actors and the healthcare system, aimed at covering the whole area of biomedicine.

The findings and conclusions have been iterated on several occasions with the process management as well as the board of GöteborgBIO, representing some main regional actors: Region Västra Götaland (VGR), Business Region Göteborg (BRG), University of Gothenburg, Chalmers University of Technology, and Sahlgrenska Science Park.

**Identification and analysis of companies**

In order to identify companies active in any of the five areas and conducting R&D within Sweden a number of sources were consulted ranging from existing mappings of companies, listings from Swedish life science organisations, web searches, to asking interviewees to name industrial actors in their field. The resulting lists were validated by experts at Swedish life science organisations.

On the regional level, our aim was to identify all firms active in the five fields, while our ambitions were more modest on the national level. This means that the number of firms and employees for Sweden as a whole is approximate. We judge that all relevant larger firms are included, but that there may be smaller firms (e.g. new start-ups) that we have not identified.

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6 For example, the understanding of the field of Biomaterials and Cell Therapy is partly based on existing studies (Rickne and Sandström, 2009; Rickne et al, 2010).
8 MediconValley, SwedenBIO, GöteborgBIO, UppsalaBIO, and SULS.
9 Note that firms that function as healthcare providers are not included in the study.
For each of the regional firms economic data was accessed, and their profile and activities were mapped by using secondary sources. Also, the firms were invited to be interviewed about their activities, collaborations and views on the region. Note that due to the long-term character of product development in the Vaccines area we included, for that specific field, not only firms but also some ongoing regional business projects which had not yet become incorporated.

**The academic groups and their financing**

The regional academic groups in each of the fields were identified through discussion with scientists, clinicians and firms. The research groups were contacted for interviews and for provision of information on their profile, size, staff members, and financing.

Our analysis spans from 2000 to 2013 and we were interested in how much external funding each group has received per year and from which sources. To identify granting organisations, volumes of financing and time periods we, in an iterative process, matched the main funders (Swedish Research Council, Swedish Foundation for Strategic Research, ALF/LUA, etc.) with the groups’ own information given at web pages and in interviews (see Appendix B for a list of granting organisations). The emerging picture was confirmed with each of the research groups, and missing data points added. It should be noted that there is most probably a lack of data for the early part of the period (2000-2005), both due to lack of official data or departmental archives, and that several groups were only beginning to form and a coherent overview is therefore not available. Nevertheless, the unexpected pattern of a dramatic increase in funding from 2005, that will be presented in Chapter 5, has been confirmed to be accurate in discussion with several groups. On the contrary, the steep decline of financing at the end of the period (2010-13) signifies that applications have not been granted as yet, rather than a real reduction of financial means to these areas. This pattern mirrors that the groups seldom have long-term financial support, but rather rely on a continuous stream of short-term grants.

**Scientific output from academic groups**

To understand the scientific output in the various areas, we identified all individuals in each of the research groups. Their volume and related citation of publications were analysed, and compared to a global average in that particular field. This means that we capture the research focus which regional academic scientists work with, but do not get a picture of the total global field or how large part of this the regional scientists engage in. A number of indicators were measured, as depicted in Table 2.1.

**Clinical studies**

We aimed to map the relative regional share of clinical studies in the five areas. A web-based project database provided by ‘FoU i Sverige’ gave an overview of ongoing studies with Region Västra Göta-
land as principal. Relevant projects were identified using MeSh terms as indicated by interviewed researchers.

**Table 2.1 Indicators of scientific strength.**

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<thead>
<tr>
<th>Indicators</th>
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</thead>
<tbody>
<tr>
<td>Number of unique publications (P)</td>
</tr>
<tr>
<td>Number of fractionalized publications, where each publication is divided by the number of authors and only author fractions connected to the regional group is counted. (Frac P)</td>
</tr>
<tr>
<td>Number of unique publications found in the Web of Science Database (PWoS)</td>
</tr>
<tr>
<td>Number of citations recorded to all publications found in the Web of Science Database. Self-citations - citations made by authors with at least one author name in common with the analysed authors - were excluded. (C)</td>
</tr>
<tr>
<td>Mean journal citation score, which is a reference value for the average citation rate of all articles published in the journals in which a research unit has published, and where self-citations are excluded. (JCSm)</td>
</tr>
<tr>
<td>Mean field citation score which is a reference value of the average citation rate of all articles in the subfields in which the research unit is active, and where self-citations are excluded. (FCSm)</td>
</tr>
<tr>
<td>Journal-normalised citations, which is the impact of a research unit’s articles, compared to the average citation rate of the research unit’s journal set. (CPP/JCSm)</td>
</tr>
<tr>
<td>Field-normalised citations, which is the impact of a research unit’s articles, compared to the world citation average in the subfields in which the research unit is active. (CPP/FCSm)</td>
</tr>
<tr>
<td>Article impact. Mean normalised citation score: Comparable to CPP/FCSm, but generated by calculating the average of the C/FCS of the individual analysed publications. (MNCS)</td>
</tr>
<tr>
<td>Mean normalised citation score for journal: Comparable to CPP/JCSm, but generated by calculating the average of the C/JCS of the individual analysed publications. (MNCSj)</td>
</tr>
<tr>
<td>Field-normalized journal citations: Impact of the journals in which a research unit has published, compared to the world citation average in the subfields covered by these journals. (JCSm/FCSm)</td>
</tr>
<tr>
<td>Fraction of papers in top5% most cited papers: Does the group have an average representation among the top 5% most cited papers? (Top5%)</td>
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<tr>
<td>Fraction of papers in top20% most cited papers: Does the group have an average representation among the top 20% most cited papers? (Top20%)</td>
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**Policy schemes**

We have mapped the policy schemes of the regional policy organisations. This includes Region Västra Götaland, which is responsible for the healthcare services, as well as Business Region Göteborg, a non-profit organisation formed by thirteen municipalities in the Gothenburg region and focused on promotion of trade and industry. Our examination also included the two universities in the city of Gothenburg – University of Gothenburg and Chalmers University of Technology – and the main healthcare organisation in Gothenburg – Sahlgrenska University Hospital. For all these actors we identified both their official statements and strategies of regional policy towards the areas and the current directed support measures.

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15 http://www.researchweb.org/is/sverige. ‘FoU i Sverige’ is a national portal providing R&D information primarily for personnel in the healthcare sector.

16 Medical Subject Headings, MeSH, entail sets of terms describing medical subfields in a hierarchical manner, enabling search at various levels of specificity.

17 Our intention was to match this data with the volume of clinical studies carried out in the entire country – within the respective area of strength. This turned out to be undoable, due to difficulties to gain access to relevant data. We also wanted to collect information about industry-sponsored clinical trials, for example, through the Regional Ethical Review Board. However, it turned out that they did not have the necessary resources to assist us.

18 There are additional universities and healthcare organisation in the region – but outside of Gothenburg. These were not included in the analysis.
Also, the support of bridging organisations, i.e. organisations set up to support e.g. innovative and growth activities of this region or sector, was charted. The bridging organisations included were GöteborgBIO, Sahlgrenska Science Park, Gothenburg for Entrepreneurship (G4E), Innovationsbron Väst, GU Holding, Microwave Road, MedTech West, and Center of Visualization Göteborg (CVG).

Information was found through official web pages, policy documents, strategic plans, etc., as well as through lists of grants and other financial support to the firms, clinics or research groups. Also, interviews with the policy actors and the bridging organisations, and with firms, clinics or research groups revealed additional information, for example on more informal support.

**Networks and collaborations**

Our aim was to identify some of the currently most important regional networks and collaborations. While national and foreign links and collaborations may be as important, or more, we are here only focused on the regional patterns. Therefore, while we have some information about national and international linkages these have not been systematically mapped in this study.

Through interviews as well as secondary information of the sector we have identified some key links between the regional actors. As we have interviewed one or two individuals per organisation and done so at a specific point in time, these network illustrations are by no means complete. Rather, the network pictures only illustrate current linkages and signify the types of actors cooperating, and the density of networks in one area as compared to another.

**Acknowledgements**

We are grateful to all persons who have generously contributed to this study. This includes more than 80 people who have been interviewed (see Appendix A) as well as others who have provided us with information or performed services on our behalf (such as, e.g., helped us with bibliometric analyses). We would also like to thank GöteborgBIO’s board and management team for valuable comments and feedback during the process. Thanks also go to the Institute for Management of Innovation and Technology (IMIT) for providing the administrative seat for our work and to Azadeh Mehrabi for helping us with some data collection.

3 **The biomedical sector in the region**

Unlike Stockholm-Uppsala and Malmö-Lund, Gothenburg (and Western Sweden in general) has not been known to have a strong cluster in life science. The truth is, however, that the greater Gothenburg region is home to a range of successful biomedical firms. Moreover, one of the largest university hospitals in Northern Europe is situated in Gothenburg and at the two universities eminent research is carried out in several biomedical sub-fields. While other industries, such as the automotive, have traditionally attracted the main interest of regional politicians and policy-makers life science has during the last decade emerged as one of the region’s prioritised sectors. A recent proof of this view is the assignment given to former Prime Minister Ingvar Carlsson to lead an investigation of opportunities and challenges in life science in Western Sweden.¹⁹

¹⁹ A preliminary report (Carlsson and Norrman, 2011) was released on 30 March 2011. It includes a number of measures that the authors recommend the region to take in order to strengthen the international competitiveness of the life science sector and stimulate growth.
This chapter provides a short overview of the biomedical sector in Western Sweden as a background to the subsequent analysis of the five focal areas of strength.\textsuperscript{20} If we start with industry we can first conclude that there are more than 200 firms that can be termed “biomedical”, in keeping with a broad definition that includes firms active in pharmaceuticals, diagnostics, medical technology and biotech supply. From an economic point of view the industry is dominated by a small number of firms that carry out major industrial activities and have a comparatively large number of employees in the region: AstraZeneca R&D Mölndal, Astra Tech, Getinge, Nobel Biocare, Mölnlycke Health Care, and SCA’s product segment for incontinence care. The first one is mainly an R&D facility and the only one from the pharmaceutical sub-sector. All the other five are medical technology (“medtech”) companies.

AstraZeneca’s R&D site in Mölndal is one of the group’s largest R&D facilities working with both discovery and development of drugs. For many years the main focus has been on the cardiovascular and gastrointestinal therapeutic fields. The R&D activities are now expanding into the respiratory and inflammatory field due to the closure of other R&D sites (e.g. in Lund). The Mölndal site currently has 2,200 employees making it the largest biomedical firm in Western Sweden. The site, which belonged to the Astra Group before its merger with Zeneca in 1999, has historically been very successful in developing new commercially important products, such as Seloken/Toprol and Plendil in the cardiovascular field and the ulcer medicine Losec and its follow-up Nexium. For some years (1996-2001) Losec was the best selling drug in the world. In later years, research on the Metabolic Syndrome including diabetes, obesity and related cardiovascular disorders has been a prioritised research topic. Historically, the Mölndal site has had close and successful collaboration with local research teams at the university and the university hospital. Due to the merger and the increasing globalisation of the company’s R&D activities, in combination with changes on the university and healthcare side, these connections are currently not as strong as they used to be.

Both Nobel Biocare and Astra Tech belong to the world leaders in the field of dental implants. The former is a pioneer and currently the world’s largest supplier of titanium-based dental implants. The company was formed in 1981 to commercialise Professor Per-Ingvar Brånemark’s path-breaking research on osseointegration, that is, bone-anchoring of prosthesis. Nobel Biocare is today a global company with legal site and headquarters in Switzerland. Out of its 2,400 employees some 450 are based in Sweden (approximately 130 in Gothenburg). Astra Tech, originally a supplier of single-use medical devices, has during the last decades become another leading producer of dental implants, a business area that now accounts for more than half of the company’s turnover. Astra Tech currently employs close to 900 people in Gothenburg (and approximately 2,200 in total).\textsuperscript{21}

Mölnlycke Health Care, spun off from SCA and Tamro in 1997, has two divisions: Surgical and Wound Care. The headquarters and most of the R&D are located in Gothenburg, where 320 out of the Group’s 6,700 employees are based. Manufacturing takes place in several plants none of which is located in Sweden. After the spin-off of Mölnlycke Health Care, SCA’s activities in the medical field have been totally focused on incontinence care, where it has a leading position and strong brands in

\textsuperscript{20} See Laage-Hellman et al (2007) for a more comprehensive description of the biomedical industry in Western Sweden.

\textsuperscript{21} Astra Tech currently belongs to the AstraZeneca Group. However, in June 2011 AstraZeneca announced a deal to sell Astra Tech to the American dental company DENTSPLY International. After the acquisition DENTSPLY will be the third largest producer of dental implants in the world.
the global market. The product segment is headquartered in Germany, but several key functions in marketing and R&D are located in Gothenburg where the segment has some 300 employees.

Getinge is a highly internationalised and diversified medtech company with group headquarters in southern Halland. One of its three business areas, Infection Control, is operating in the region (Getinge and Skårhman). In total, Getinge currently has about 575 employees in the region of Western Sweden.

Besides these large firms there are a fairly large number of other biomedical firms in the region. Most of them are in medical technology and are relatively small. But some of the firms have made success in the global market and grown relatively fast. Here we find, for example, Breas Medical (home care ventilation and sleep therapy), Carmel Pharma (handling of toxic drugs), and Cochlear Bone Anchored Solutions (hearing aids). The latter is a spin-off from Nobel Biocare. Vitrolife, with main focus on in-vitro fertilisation, is another successful company. Like many of the other medtech companies it is a university spin-off.

The pharmaceutical sub-sector is totally dominated by AstraZeneca. Besides this company’s R&D site in Mölndal there are only a limited number of firms engaged in drug research, and most of them are very small. The largest one is NeuroSearch, an R&D facility owned by the Danish NeuroSearch Group (with some 30 employees in Gothenburg). It is originally a spin-off from the University of Gothenburg. Albireo is another interesting company. It is a corporate spin-out from AstraZeneca’s gastro-intestinal research in Mölndal.

In the biotech supply sub-sector, there are no big companies and the number of firms is also limited. But some of the companies involved in commercialising academic research findings have managed to reach a certain size in terms of number of employees. Cellartis, a stem cell company, has grown relatively fast and has some 50 employees today. Other companies worthwhile to mention in this connection are Cellectricon (nanotechnology devices for drug screening), Q-Sense (surface analysis), and again Vitrolife (stem cell cultivation).

Beside those biomedical firms with in-house R&D and/or production in the region, some of which have been mentioned above, there are also a fairly large number of firms (probably close to hundred) which are totally focused on marketing and sales. Some of them are subsidiaries of foreign manufacturers, while others are independent distributors representing several manufacturers. In the pharmaceutical field, Gothenburg is home to two national drug distributors – Tamro and Kronans Droghandel.

Let us move on to the public actors in the biomedical sector. There are two major universities in the region: University of Gothenburg and Chalmers University of Technology (“Chalmers”). Within the former there is since 2001 one faculty inclusive of practically all health sciences, this being the Sahlgrenska Academy. It has approximately 1 400 employees and is organised into six institutes: Biomedicine, Clinical Sciences, Health and Care Sciences, Medicine, Neuroscience and Physiology, and Odontology. Sahlgrenska Academy is conducting a broad range of research activities – from basic to more applied – but has its traditional strength in clinically oriented research which is carried out in close collaboration with Sahlgrenska University Hospital, where the university's clinical departments and research groups are located. The university also has a Faculty of Sciences where research of relevance to biomedicine is carried out (e.g. at the Department of Cell and Molecular Biology).
At Chalmers, technical research of relevance to biomedicine is performed in different parts of the organisation. Since a couple of years, Life Science is one of Chalmers’ so-called areas of advance. Within this area Systems Biology, with special focus on metabolism, is a new field of research which is given high priority. At the Department of Signals and Systems there is a group working specifically on biomedical engineering.

Biomedical research is also to some extent carried out at the smaller universities outside of Gothenburg. For example, the University of Borås has started to build up a research environment in biomedical engineering, partly by recruiting key individuals from Chalmers. The University of Skövde is doing research in bioinformatics and systems biology. Halmstad University has chosen health, broadly defined, as one of its prioritised research areas.

SP Technical Research Institute, SIK (the Swedish Institute for Food and Biotechnology), and IMEGO are three publicly-owned research institutes which are located in Western Sweden and, in parallel to other activities, carry out research in the biomedical field.

Sahlgrenska University Hospital, with three major sites, is one of the largest hospitals in Northern Europe. The clinical departments of Sahlgrenska Academy are located there. The hospital has got national responsibility for several specialties, such as organ transplantation. There are some other relatively large hospitals situated outside of Gothenburg. Another key actor in the healthcare sector is Region Västra Götaland (“VGR”), which is responsible for financing and providing public healthcare services in the region. Another task is to support industrial development in the region.

There is also within the region a range of public organisations providing different kinds of innovation support, more or less dedicated to life science. We have, for example, Sahlgrenska Science Park, Chalmers Innovation, GU Holding, and Innovationsbron Väst. Industrifonden, a state-owned venture capital firm, has a branch in Gothenburg.

To conclude this chapter we will present three case stories that provide some insight into the historical development in three fields of particular interest from the perspective of the present study. The first case concerns biomedical engineering at Chalmers and the second deals with biomaterials research in Gothenburg. The third case gives an historical account of the cardiovascular research in Gothenburg.

**Historical case: Biomedical engineering at Chalmers**

Chalmers is one of three Swedish universities where academic research in medical technology (or biomedical engineering which is here used as a synonymous term) began to emerge in the 1940s/50s. The other two were Karolinska Institutet and Lund Institute of Technology.

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22 The case descriptions are based on data collected for previous studies, in first place Laage-Hellman et al (2009).

23 From an international perspective, medical technology as a research field began to appear in the 1940s. There were for example clinical physiologists or other physicians within the faculties of medicine who were interested in technology and began to develop new techniques and instruments, which they needed primarily for their own medical research (rather than for treatment or diagnosis of patients). At the same time, technical research dealing specifically with the development of new methods, apparatuses and other types of products to be used in healthcare began to appear at some universities of technology. Commonly, research groups with such a focus were formed within departments of electrical engineering (where medical technology became one of several application fields – typically one of the smaller).

24 A couple of decades later, in the 1970s, Linköping Institute of Technology became a major Swedish centre for education and research in the field of biomedical engineering.
At Chalmers, research on applied electronics with a focus on medical applications began with Professor Henry Wallman. He was an American mathematician from MIT who had been recruited by Chalmers. For personal reasons he became interested in medical technology and started pioneering research on X-ray television. He also began to build up a research group and broadened the scope to cover other technologies and applications. Signal processing at an early stage became a core area. The second half of the 1970s and the first half of the 1980s can be characterised as a flourishing period from a medtech point of view. The Department of Applied Electronics had two full professors and practically all research was focused on bioengineering. A tradition of close collaboration with clinicians at the nearby Sahlgrenska University Hospital was established. Doctoral projects were sometimes carried out by pairs of students – one from Chalmers and one from the medical faculty at the University of Gothenburg (so-called pair theses).

However, despite internationally well-recognized research and interesting results commercialisation was rare. It turned out to be difficult to get established medtech firms interested in taking over the knowledge and inventions and bringing them to the market. It was against that background that Chalmers established a foundation called Medicin & Teknik in 1985. The main purpose was to further develop and prepare commercially interesting projects for exploitation. Besides a number of successful consulting projects for existing firms (e.g., the newly established Ortivus Medical), the main outcome of Medicin & Teknik’s activities is the founding in 1991 of a company called Svenska Telemedicin System. This start-up was six years later acquired by Ortivus Medical and is the origin of one of the company’s present core businesses. There are a few other companies which over the years have spun off from the department, with or without support from Medicin & Teknik: P&B Sound System (1985),25 Neoventa Medical (1997), Osseofon (1997), SACS Medical (2002), Oiido (2002), and Medfield Diagnostics (2005). Generally, the results of these commercialisation efforts must be regarded as rather disappointing – so far. The number of start-ups is low and none of them have become a high-growth company. A more successful case is the development and commercialisation of a bone-anchored hearing device. This is an invention made by a small team of researchers and originally licensed, via P&B Sound System, to an existing firm – Nobelpharma (i.e., today’s Nobel Biocare). The hearing aids business was in 1999 spun off from Nobel Biocare and later on acquired by the Australian firm Cochlear Limited. The new parent company has continued to invest in its Swedish subsidiary, Cochlear Bone Anchored Solutions, which has grown relatively fast. In 2009, it had 134 employees and reached a turnover amounting to SEK 360 million.

At the Department of Applied Electronics, the volume of medtech research peaked in the late 1970s and the first half of the 1980s, with two full professorships and in total more than 30 people involved in biomedical engineering. Besides the general university funds, the research funding came from several external sources. In addition to grants from various government agencies and the EU substantial funding was during one period received from Televerket (the Swedish Telecommunications Administration).

From the late 1980s and onwards the volume of medtech research at the department began to shrink. First one of the professors and later on the other retired and none of them were substituted by persons working in the field of biomedical engineering. Gradually, the department’s research came to focus more on signal processing in general and on other (non-medical) applications. Some

25 Later P&B Research.
people left, but a small group of researchers dedicated to bioengineering remained. In the early 2000s, there were only about ten people active in the area. But around the same point in time the downward trend was broken and since then the medtech-oriented research has experienced a revival, meaning that the number of people and the research volume have gradually increased. This positive development has been driven by a small group of dedicated individuals, who have managed to get support both from Chalmers and from other actors in the local environment. An important event that took place a couple of years ago was the creation of MedTech West. This is a kind of network organisation supported by Region Västra Götaland, Sahlgrenska University Hospital, Chalmers, University of Gothenburg and University of Borås. The purpose is to create a regional platform for joint development and innovation. MedTech West also aims to serve as a natural entry point for companies that want to participate in needs-driven and interdisciplinary collaboration with clinical and technical researchers. Besides the existing contacts with regional firms, efforts have been made to establish collaboration also with leading medtech companies located in other parts of Sweden (i.e. firms like Elekta and St Jude Medical).

Thus, the medtech research related to signal processing at Chalmers is now on the rise again and a master’s programme in biomedical engineering has been established as a core activity. At present, there are four research groups, each one headed by a professor, which are focusing on different fields. In total, the Department of Signals and Systems as it is now called has some 20 researchers within its Division of Biomedical Engineering. As part of the MedTech West initiative conscious efforts are made to increase collaboration both within Chalmers and with other actors in the region as well as in other parts of Sweden.

**Historical case: Biomaterials research in Gothenburg**

As already mentioned biomaterials is seen as one of the region’s areas of strength. This goes back to Professor Per-Ingvar Brånemark’s pioneering research on titanium implants and osseointegration in the 1950s, 60s and 70s. He was from the beginning working at the University of Gothenburg’s Department of Anatomy, but later on a department dedicated to biomaterials science was created (2001).

Per-Ingvar Brånemark’s research, which more and more came to focus on dental applications, led to the formation of a company – Nobelpharma, later on renamed to Nobel Biocare. The company was founded by Bofors (which later became a member of the Nobel Industries Group) in 1981. Thus, being fully financed by a large corporation Nobelpharma was not a typical university spin-off. But the purpose was to commercialise the discoveries and inventions made by Per-Ingvar Brånemark and his co-workers at the university.

After a long, difficult and resource-demanding commercialisation process Nobelpharma/Nobel Biocare managed to create a profitable and expanding business in dental implants, where it now has a world-leading position. Nobelpharma was in 1996 spun off from Nobel Industries, and a few years later Swiss investors took control over the company. The headquarters was moved from Gothenburg.

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26 It should be noted that medtech research is carried out also at other departments at Chalmers, such as the Department of Applied Physics and the Department of Chemical and Biological Engineering.
27 This case does not cover all biomaterials-related research in Gothenburg. It deals primarily with metallic implants, where the region has a long and successful history, both scientifically and industrially. This means that some other biomaterials-related research activities of a more recent date, for example in the polymer field, are not covered. This does not mean that this research is less successful or of less importance for the future development of the region’s biomedical innovation system.
to Zürich. A number of non-dental applications (hearing aids and craniofacial prostheses) for which the company had also obtained a licence were in 1999 spun off from Nobel Biocare by creating a new company, Entific Medical Systems. This corporate spin-off was in 2005 acquired by the Australian firm Cochlear. Cochlear Bone Anchored Solutions, which is the current name of the Swedish subsidiary, is since then continuing to grow.

On the academic side, Per-Ingvar Brånemark’s group at the University of Gothenburg developed from 1979 and onwards a close research collaboration with a group from Chalmers’ Department of Physics headed by Professor Bengt Kasemo. Thanks to long-term and forward-looking financing from the predecessors of today’s Vinnova (i.e. STU and Nutek) and from the Swedish Foundation for Strategic Research (“SSF”) the biomaterials research at both universities expanded during the 1980s and 90s and an internationally strong research environment emerged. Close links were also established with other biomaterials-oriented research groups in other parts of Sweden. For example, Professor Ingemar Lundström’s group in Linköping became an important partner.

Parallel to the publicly funded research projects the biomaterials groups at both universities developed fruitful collaboration with Nobelpharma/Nobel Biocare. For example, in the 1990s the company financed several PhD students at Chalmers.

Towards the end of the 1990s Chalmers’ collaboration with Nobelpharma/Nobel Biocare was winded up. Dental implants had become an established product and the material issues were of less interest from an academic point of view. The Chalmers group therefore began to reorient its research into new directions such as biosensors, tissue engineering and drug screening. Instead, SP in Borås, which had recruited some biomaterials researchers from Chalmers, took over the collaboration with Nobelpharma/Nobel Biocare. One example is the TiUnite surface which is today applied on most dental implants manufactured by the company. The project started as a jointly financed collaboration between SP and Nobelpharma/Nobel Biocare and lasted for a few years. The project was based on knowledge from Chalmers that had been transferred to SP through recruitment. The development and characterisation of the new surface took place at SP after which clinical testing was carried out together with Nobelpharma/Nobel Biocare’s clinical partners. After having developed and validated a semi-industrial manufacturing process at SP the technology was transferred to Nobelpharma/-Nobel Biocare’s factory. But before that, when the project had approached a commercialization stage, Nobelpharma/Nobel Biocare had taken over full responsibility for the financing. At the end this project had a great impact on the company’s product development, and it can be regarded as a good illustration of how knowledge created in an academic setting can be used as an input to industrial product development.

At the University of Gothenburg a Department of Biomaterials Science was in 2001 established by bringing together two research groups headed by two pupils of Per-Ingvar Brånemark (who had retired in 1994). However, in those days it had become difficult, due to organisational and policy changes in the research financing system, to obtain funding for biomaterials research from Vinnova and other national financiers. During a period of 4-5 years the biomaterials researchers at the universities survived thanks to grants from the EU and support from industry. For example, the Department of Biomaterials carried out bilateral contract research projects both for Nobel Biocare and Astra Tech. The latter had by that point in time started to build up a business in titanium-based dental implants, thereby becoming one of Nobel Biocare’s toughest competitors in the global mar-
ket. These collaborations became important both to the academic researchers and to the companies. Specific research findings as well as more general scientific competencies were transferred to the companies, for example, through recruitment of PhD graduates.

Despite positive outcomes the academic researchers were not entirely happy about this bilateral form of collaboration. It made them dependent on the companies and there was also a tendency for the researchers to serve as merely “suppliers of data”. Another type of industrial collaboration, which was perceived to be more rewarding from an academic point of view, was established with two other firms: Artimplant and Mölnlycke Health Care. Both companies were searching for new biological knowledge in an open-minded way, and working together with them was stimulating and led to renewal of the research orientation. That means a reorientation away from titanium implants to other materials and other concepts (like degradable implants).

As described here the industry collaboration has primarily taken place with existing firms. This may explain why there has been little interest in starting up new firms. One exception, though, is Q-Sense. This is a spin-off founded by Bengt Kasemo and three colleagues. The surface analysis instrument successfully commercialised by this firm is a direct outcome of the research funded by STU and Nutek in the 1980s and 90s. Since its foundation in 1996 Q-Sense has maintained close contact with the research group.

In the mid-2000s, the financing situation for the biomaterials research in Gothenburg improved significantly and several valuable grants were obtained. First, biomaterials and cell therapy became a focus area within the ten-year Vinnväxt project Biomedical Development in Western Sweden (now known under its brand name GöteborgBIO). This has enabled the establishment of the Institute for Biomaterials and Cell Therapy (IBCT), where biomaterials researchers are participating in interdisciplinary multilateral projects together with several regional companies (including e.g. Nobel Biocare and Mölnlycke Health Care). These projects are applied in nature and focuses on the development of new innovative methods that industry needs in its product development. Second, since 2007 Vinnova is funding Biomatcell, a VinnExcellence Centre based in Gothenburg. The centre is hosted by the Sahlgrenska Academy, but involves researchers also from Chalmers, SP and Uppsala University. Although Biomatcell is exploring new frontlines of research – combining biomaterials with cell therapy – the centre’s activities to a large extent draw on capabilities that were built up over the years with support from various research financiers. There are several industrial partners in Biomatcell, including large as well as small companies coming from different parts of Sweden. The involvement of these firms in the research is expected to have positive effects on the research environment, quantitatively and qualitatively, and contribute to further strengthen Gothenburg’s position as an international leader in biomaterials research.

By combining biomaterials and stem cell research Biomatcell applies a unique approach to tissue engineering that differs from the path commonly followed abroad, for example, in the USA. There are hundreds of American start-ups in the field but few of them have managed to reach the market. Tissue engineering is a field where Sweden has not spent large resources in the past, but it is expected that Biomatcell’s approach will give Sweden an opportunity to become a key player internationally in regenerative medicine.

Parallel to this reorientation of the biomaterials research in Gothenburg, in the direction towards tissue engineering and regenerative medicine, the collaboration with the dental implants companies
Nobel Biocare and Astra Tech continues. The former is involved in IBCT and the latter participates in academic research activities. For instance, Astra Tech's R&D Director (a previous PhD graduate from Sahlgrenska Academy) has an adjunct professorship at the university.

In recent years the academic researchers’ interface with industry has been broadened. Besides the collaborations taking place within the frame of GöteborgBIO and Biomatecell, contacts have been established with a large number of European firms, mainly small ones and through EU projects. One example is a small London-based orthopaedic company which is developing new better surfaces for implants. The Department of Biomaterials Science gives the company advice on different materials-related matters and also carries out small assignments.

**Historical case: Cardiovascular research in Gothenburg**

Starting in the 1960s strong research groups in the field of cardiovascular research began to be formed within the medical faculty of the University of Gothenburg. At the Department of Medicine Professor Lars Werkö built up a strong clinical research environment focusing on cardiology. In parallel, under the leadership of Professor Björn Folkow at the Department of Physiology a group working more on the vascular side was established. The 1970s and 1980s became a golden age for cardiovascular research in Gothenburg, both from an academic and industrial standpoint. For example, the move of an entire clinical research group in epidemiology to Östra Hospital in 1978 turned out to be a fortunate initiative and resulted in very active patient-based research.

The expanding groups produced research results that were both scientifically high-standing and industrially relevant. Both environments established close collaboration with Astra’s R&D site in Mölndal, which likewise expanded substantially during this period. An important outcome of the collaboration was the development of betablockers. Astra’s Seloken/Toprol, launched for treatment of hypertension already in 1975, became a commercial success. Later, after having changed the formulation and added new significant indications such as heart failure, it even became a so-called blockbuster. Furthermore, when Astra developed ACE inhibitors based on in-licensed substances from Germany and Japan large-scale clinical studies were carried out at Sahlgrenska University Hospital. Atacand, licensed from Takeda, is still today one of AstraZeneca’s best selling products. In the late 1980s and mid-1990s major population-based studies on other cardiovascular diseases (e.g. myocardial infarction and heart failure) were managed by local clinical partners in Gothenburg and helped the company to develop and bring to the market new products.

It can be noted that in parallel to these activities Gothenburg emerged as a strong centre also in epidemiology. Today’s well-reputed epidemiology research on diabetes and cardiovascular diseases builds on this tradition, which dates back to the 1960s. Unlike the clinical research mentioned above these scientifically high-quality studies do not seem to have had direct effects on industry, but the produced knowledge has instead benefitted society in other ways (e.g., by changing clinical guidelines and improving health planning).

When Professor Lars Werkö in 1975 left the university to become head of Astra’s R&D there were other prominent researchers, such as professors Åke Hjalmarsson and Finn Waagstein, who took over the leadership and continued to develop the environment and bring forward new significant research findings, some which were successfully commercialised by Astra among others (e.g. the use of betablockers for treatment of heart failure). The industrial partners consisted of large pharmaceutical firms as well as Swedish and foreign medtech companies (including, e.g., Ortivus Medical and Medtronic). Professor Karl Swedberg led further initiatives to the improvement in treatment of
chronic heart failure from Östra Hospital. This included the development of ACE inhibitors and angiotensin receptor blockers in collaboration with MSD and Astra.

In the 1990s the cardiovascular research environments in Gothenburg began to decline. For example, in physiology the research in Gothenburg failed to integrate modern molecular biology and for a long time kept to the more traditional approach. This turned out to be unfortunate. Furthermore, some of the leading researchers in medicine and cardiology, such as Claes Wilhelmsson and Anders Vedin, had already in the 1980s been recruited by Astra to take up senior management positions. Later, other researchers from the same environment got professorships at other universities in Sweden, which were trying to catch up with Gothenburg. In addition, others retired without being substituted (in a few cases, though, VGR stepped in and took over the financing responsibility). It seems that to a large extent the university failed to handle the succession problem and secure a continued strong scientific leadership. To maintain the leading position recruitment of key individuals from outside the region would probably have been necessary, but this did not happen. What remains today from the golden age of clinical cardiovascular research are a few niches, notably research on heart failure and lipids). The strong tradition in epidemiology has also survived and is now flourishing.

In explaining Gothenburg’s weakening position in cardiovascular research some of the interviewed professors point to the gradually deteriorating collaboration between the university hospital and the academic research as one contributing factor. They mean, for example, that the lack of strategic coordination between the two organisations has negatively affected the conditions for carrying out clinical research.

It seems, however, that during the last few years this negative trend has been broken and the cardiovascular research in Gothenburg is regaining strength. Thanks to a major grant a large centre for more basic/experimental research was created in the mid-2000s (Sahlgrenska Centre for Cardiovascular and Metabolic Research, CMR). The main focus is on diabetes, obesity and related cardiovascular diseases. Diabetes, generally, is a field where Gothenburg has succeeded to maintain strong academic research over a long period of time. Prominent groups have been integrated in CMR. Also on the clinical side there are promising developments in terms of expansion and formation of new groups. At least one strategic recruitment from another university (Karolinska Institutet) has been made. Both the University of Gothenburg and VGR have contributed to new professorships. Other initiatives aiming to improve the collaboration between the universities and the healthcare are also seen by our interviewees as positive. But there are also those who claim that there is still need for better strategic alignment among the key actors.

In parallel to the decline of the research environments at the university Astra changed its research strategy. As a consequence, much of the traditional cardiovascular research at the discovery level, for example on hypertension and myocardial infarction, was terminated or substantially reduced (partly due to patent expiry for key products). However, research on antithrombotic agents continued. Moreover, the Metabolic Syndrome, related to e.g. diabetes, obesity and high cholesterol, became a highly prioritised research topic. These changes contribute to explain why the traditionally close collaboration between the R&D site in Mölndal and Sahlgrenska University Hospital to a large extent ceased. However, instead the company has established a deeper collaboration with CMR. The prerequisites for collaboration have also been affected by Astra’s merger with Zeneca in 1999. The site became an integrated part of a global corporation. Related organisational changes have made it
more difficult for the company to have the type of open and often informal collaboration that
existed in the past.\textsuperscript{28} It is noteworthy, however, that senior representatives of the Mölndal site now
express interest in re-establishing closer ties with the clinical research in Gothenburg.

Besides those research fields mentioned above, Gothenburg has also built up a strength position in
heart transplantation and cardiovascular surgery in general. Sahlgrenska University Hospital was a
national pioneer in heart transplantation and has now got national responsibility for performing this
type of surgical intervention (together with Region Skåne). The clinical activities are supported by
academic research.

4 Industrial activity

The five analysed areas are industrially important and roughly account for two thirds of the Indus-
trial employment within biomedicine in the region. Another indicator of strength is that the region
accounts for a large share of the Swedish industry in these five areas: 31 percent of the firms and 36
percent of the employment.

The regional industry is particularly strong in two areas. First, in Biomaterials and Cell Therapy
almost half of the national firms in this field are located in Western Sweden. This is illustrated in
Figures 4.1 and 4.2 which show the geographical distribution of firms and employment respectively.
In this area of strength we have a true cluster with a relatively large number of firms as well as other
actors which are connected to each other through a web of collaborative relationships. There are
several commercially successful companies, some of which have world-leading positions in their
respective market niches – for example Nobel Biocare and Astra Tech in dental implants. Another
sub-field where the region is internationally strong is bone-anchored hearing aids where both of the
world’s suppliers of such products are located in Gothenburg.

Second, also in the Cardiovascular and Metabolic Diseases area the regional industry is strong in re-
lation to the rest of Sweden, but for a totally different reason. There is one large and dominant firm,
namely AstraZeneca R&D Mölndal with approximately 1 400 employees working in the area (out of
2 200 employees in total). Apart from AstraZeneca there are only a limited number of small firms,
and here one cannot talk about a cluster as in the previous area.

In Medical Signal Processing and Visualisation, about one fifth of the Swedish companies are located
in Western Sweden – and about 15% of the employment. This roughly corresponds to the average
figure for the region’s national position in the entire life science sector. It should be pointed out,
however, that in this case the definition of the area makes it particularly difficult to make delimit-
tation. Especially signal processing is a type of technology used by many medical technology com-
panies. It is therefore not obvious which companies that should be included or not. Nonetheless, it is
fairly clear that in Medical Signal Processing and Visualisation the strength of the regional industry
from a national perspective is not comparable to the two previously mentioned areas. It is true that
there are a relatively large number of firms but there are no big ones among them and the industry

\textsuperscript{28} Several of the interviewed professors at Sahlgrenska University Hospital question if Seloken/Toprol could have been
developed in today’s situation. “In the past, the Mölndal site could take its own decisions. Today, the decisions are made
by a board at the corporate headquarters in London”, as one of them says.
is rather fragmented – that is, the companies tend to operate in different sub-fields and do not have so tight connections to each other.\textsuperscript{29}

\textbf{Figure 4.1} \hspace{1em} \textit{Geographical distribution of firms.}

Also in \textit{Neurological Diseases}, the regional industry is relatively weak in a national context (one fourth of the firms and 15\% of employment). Besides a newly started company without employees, there are two companies dedicated to the area (NeuroSearch and A. Carlsson Research) and there is one for which neuro is one of several therapeutic fields (Cellartis).

In the \textit{Vaccines} area, the region is very weak industrially. There are only two small companies. However, it is worthwhile to mention that there are three recent business projects which may be transformed into real companies in a near future.\textsuperscript{30} Nevertheless, it is important to set the possibilities of

\textsuperscript{29} As described in Chapter 3’s historical case on biomedical engineering at Chalmers, the region has a long tradition of academic research in medical signal processing, mainly thanks to Chalmers which was doing pioneering research already in the 1950s. The research was often carried out in close co-operation with Sahlgrenska University Hospital. Over the years, conscious attempts have been made to commercialise research findings, for example by starting up new firms, but the outcome has been rather disappointing from a growth point of view.

\textsuperscript{30} Although there is no vaccine industry in Gothenburg, it is worth mentioning that academic research in the 1990s laid foundation for successful development and commercialisation of a drinkable cholera vaccine. The product was brought to
the region in relation to the overall activity in Sweden with in total 11 companies and an employment figure of 183 people.\footnote{31}

\textit{Figure 4.2} \textit{Geographical distribution of employees.}

To summarise, Table 4.1 gives an overview of the number of firms and the number of employees in the region and in Sweden respectively for 2009. It is clear that more than half of the regional firms and their employment within the analysed areas of strength are in \textit{Biomaterials and Cell Therapy}, and without doubt this is a strong field. Other areas have several small firms which have not reached a strong growth. Whilst 28\% of the firms relates to \textit{Medical Signal Processing and Visualisation}, only 8\% of the employment does. On the far other end of that scale is \textit{Cardiovascular and Metabolic Diseases} with 20\% of firms and 33\% of employment.

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\footnote{31 In August 2011 one of the Swedish vaccine companies, the publicly listed Diamyd Medical, announced that it will discontinue its vaccine research and lay off some twenty employees.}
Table 4.1  Overview of firms and employees in the region and in Sweden (2009).

<table>
<thead>
<tr>
<th>Area</th>
<th>Approx. number of firms in Sweden</th>
<th>Number of firms in the region</th>
<th>Approx. number of employees in Sweden</th>
<th>Number of employees in the region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomaterials and Cell Therapy</td>
<td>57</td>
<td>27</td>
<td>5 573</td>
<td>2 256</td>
</tr>
<tr>
<td>Vaccines</td>
<td>11</td>
<td>2</td>
<td>183</td>
<td>3</td>
</tr>
<tr>
<td>Medial Signal Processing and Visualisation</td>
<td>61</td>
<td>14</td>
<td>1 985</td>
<td>340</td>
</tr>
<tr>
<td>Neurological Diseases</td>
<td>17</td>
<td>4</td>
<td>587</td>
<td>87</td>
</tr>
<tr>
<td>Cardiovascular and Metabolic Diseases</td>
<td>37</td>
<td>10</td>
<td>3 156</td>
<td>1469</td>
</tr>
<tr>
<td>Total*</td>
<td>168</td>
<td>50</td>
<td>9 542</td>
<td>4 130</td>
</tr>
</tbody>
</table>

* Adjusted for companies present in more than one area

Tables 4.2-4.7 provide some key information about the regional firms in each area of strength, where the number of employees and revenues are from 2009. In the case of vaccines we have added one table covering three ongoing business projects which have not yet become incorporated (Table 4.4).

Table 4.2  Regional firms in the area of Biomaterials and Cell Therapy.

<table>
<thead>
<tr>
<th>Name of company</th>
<th>USO/CSO-Founder</th>
<th>Founded</th>
<th>Main focus</th>
<th>No. of empl</th>
<th>Revenues (MSEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abigo Medical</td>
<td>Entr.</td>
<td>1988</td>
<td>Pharmaceuticals</td>
<td>35</td>
<td>86.7</td>
</tr>
<tr>
<td>Anatomica Surgical Products</td>
<td>Entr.</td>
<td>1981</td>
<td>Spine surgery and trauma</td>
<td>4</td>
<td>10.6</td>
</tr>
<tr>
<td>Arterion</td>
<td>USO</td>
<td>2007</td>
<td>Artificial blood vessels</td>
<td>3</td>
<td>0.02</td>
</tr>
<tr>
<td>Arcam</td>
<td>USO</td>
<td>1997</td>
<td>Production technology for medical implants</td>
<td>36</td>
<td>74.5</td>
</tr>
<tr>
<td>Artimplant</td>
<td>USO</td>
<td>1991</td>
<td>Degradable implants</td>
<td>27</td>
<td>24.4</td>
</tr>
<tr>
<td>Astra Tech</td>
<td>Astra</td>
<td>1948</td>
<td>Dental implants and medical devices</td>
<td>865</td>
<td>2 210</td>
</tr>
<tr>
<td>Biopolymer Products of Sweden</td>
<td>USO</td>
<td>1999</td>
<td>Mussel adhesive protein</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>Bohus BioTech</td>
<td></td>
<td>1994</td>
<td>Hyaluronic acid</td>
<td>30</td>
<td>53.7</td>
</tr>
<tr>
<td>Brånemark Center Göteborg</td>
<td>USO</td>
<td>1994</td>
<td>Dental implants</td>
<td>4</td>
<td>12.4</td>
</tr>
<tr>
<td>Brånemark Integration</td>
<td>USO</td>
<td>2001</td>
<td>Osseointegration</td>
<td>7</td>
<td>4.9</td>
</tr>
</tbody>
</table>

32 In these tables the year of foundation refers to the present firm’s activities. It should be noted that the name of the firm might have changed since its start due to e.g. acquisition. We distinguish firms that have been formed through university spin off (USO) and corporate spin off (CSO). Entr. means that the firm is not a USO or CSO but has been founded by "an independent entrepreneur" (e.g. someone who has worked in the industry before).

33 Note that there is some overlap of firms since some companies are active in more than one area.
<table>
<thead>
<tr>
<th>Name of company</th>
<th>USO/CSO</th>
<th>Founded</th>
<th>Main focus</th>
<th>Number of employees</th>
<th>Revenues (MSEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellartis</td>
<td>USO</td>
<td>2001</td>
<td>Stem cells</td>
<td>50</td>
<td>53.4</td>
</tr>
<tr>
<td>CellMatrix</td>
<td>USO</td>
<td>1999</td>
<td>Transplantation products</td>
<td>1</td>
<td>4.3</td>
</tr>
<tr>
<td>Cochlear Bone Anchored Solutions</td>
<td>CSO</td>
<td>1999</td>
<td>Bone-anchored hearing aids</td>
<td>134</td>
<td>362.7</td>
</tr>
<tr>
<td>Craniofacial Reconstruction TA</td>
<td></td>
<td>1990</td>
<td>Cranofacial implants</td>
<td>5</td>
<td>3.0</td>
</tr>
<tr>
<td>Elos Medtech</td>
<td></td>
<td>1923</td>
<td>Medical technology</td>
<td>116</td>
<td>105.3</td>
</tr>
<tr>
<td>Integrum</td>
<td>USO</td>
<td>1990</td>
<td>Bone anchoring</td>
<td>6</td>
<td>15.1</td>
</tr>
<tr>
<td>Mölnlycke Health Care</td>
<td>CSO</td>
<td>1997</td>
<td>Wound care and surgical products</td>
<td>323</td>
<td></td>
</tr>
<tr>
<td>Neoss</td>
<td></td>
<td>2005</td>
<td>Dental implants</td>
<td>8</td>
<td>11.4</td>
</tr>
<tr>
<td>NidaCon International</td>
<td></td>
<td>1997</td>
<td>IVF products</td>
<td>12</td>
<td>15.2</td>
</tr>
<tr>
<td>Nobel Biocare</td>
<td>CSO</td>
<td>1981</td>
<td>Dental implants</td>
<td>130</td>
<td>3 122.5</td>
</tr>
<tr>
<td>Ostell</td>
<td>USO</td>
<td></td>
<td>Implants diagnostics</td>
<td>12</td>
<td>28.3</td>
</tr>
<tr>
<td>Oticon Medical</td>
<td>Entr.</td>
<td>2004</td>
<td>Bone-anchored hearing aids</td>
<td>10</td>
<td>17.3</td>
</tr>
<tr>
<td>P&amp;B Research</td>
<td>USO</td>
<td>1985</td>
<td>Bone-anchored hearing aids</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Promimic</td>
<td>USO</td>
<td>2004</td>
<td>Implant surface</td>
<td>6</td>
<td>1.2</td>
</tr>
<tr>
<td>Q-Sense</td>
<td>USO</td>
<td>1996</td>
<td>Surface analysis</td>
<td>9</td>
<td>26.2</td>
</tr>
<tr>
<td>SCA Incontinence Care (product area within SCA)</td>
<td></td>
<td></td>
<td>Incontinence products</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Vitrolife</td>
<td>USO</td>
<td>1989</td>
<td>IVF products</td>
<td>119</td>
<td>276.4</td>
</tr>
</tbody>
</table>

**Table 4.3  Regional firms in the area of Vaccines.**

<table>
<thead>
<tr>
<th>Name of company</th>
<th>USO/CSO</th>
<th>Founded</th>
<th>Main focus</th>
<th>Number of people involved</th>
<th>Revenues (MSEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immunicum</td>
<td>USO</td>
<td>2002</td>
<td>Cancer</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
<td>MIVAC Development</td>
<td>USO (GU Holding)</td>
<td>2005</td>
<td></td>
<td>1</td>
<td>1.1</td>
</tr>
</tbody>
</table>

**Table 4.4  Vaccine-based business projects in the region.**

<table>
<thead>
<tr>
<th>Name of project</th>
<th>USO/CSO</th>
<th>Main focus</th>
<th>Number of people involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auremune</td>
<td>USO</td>
<td>Allergy</td>
<td>2</td>
</tr>
<tr>
<td>Simplexia</td>
<td>USO</td>
<td>Genital herpes</td>
<td>2</td>
</tr>
<tr>
<td>Traccine Pharmaceuticals</td>
<td>USO</td>
<td>Chlamydia</td>
<td>1</td>
</tr>
</tbody>
</table>
### Table 4.5  
**Regional firms in the area of Medical Signal Processing and Visualisation.**

<table>
<thead>
<tr>
<th>Name of company</th>
<th>USO/CSO Founder</th>
<th>Founded</th>
<th>Main focus</th>
<th>Number of employees</th>
<th>Revenues (MSEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bellman &amp; Symfon</td>
<td>Entr.</td>
<td>1989</td>
<td>Hearing aids</td>
<td>27</td>
<td>49.5</td>
</tr>
<tr>
<td>Cochlear Bone Anchored Solutions</td>
<td>CSO</td>
<td>1999</td>
<td>Bone anchored hearing aids</td>
<td>134</td>
<td>362.6</td>
</tr>
<tr>
<td>Medfield Diagnostics</td>
<td>USO</td>
<td>2005</td>
<td>Acute stroke treatment</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Mentice</td>
<td>Entr.</td>
<td>1998</td>
<td>Medical simulation</td>
<td>44</td>
<td>70.8</td>
</tr>
<tr>
<td>Micropos Medical</td>
<td>USO</td>
<td>2003</td>
<td>Radiotherapy</td>
<td>4</td>
<td>0.2</td>
</tr>
<tr>
<td>MultiID Analysis</td>
<td>USO</td>
<td>2001</td>
<td>Multidimensional data analysis</td>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td>Neoventa Medical</td>
<td>USO</td>
<td>1997</td>
<td>Neonatal</td>
<td>22</td>
<td>23.3</td>
</tr>
<tr>
<td>Osseofon</td>
<td>USO</td>
<td>1997</td>
<td>Hearing aids</td>
<td>0</td>
<td>0.9</td>
</tr>
<tr>
<td>Oticon Medical</td>
<td>Entr.</td>
<td>2004</td>
<td>Bone-anchored hearing aids</td>
<td>10</td>
<td>17.3</td>
</tr>
<tr>
<td>P&amp;B Research</td>
<td>USO</td>
<td>1985</td>
<td>Bone-anchored hearing aids</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Qualisys</td>
<td>USO</td>
<td>1989</td>
<td>Optical motion capture</td>
<td>17</td>
<td>41.6</td>
</tr>
<tr>
<td>RTI Electronics</td>
<td>Entr.</td>
<td>1981</td>
<td>X-ray QA solutions</td>
<td>37</td>
<td>42.6</td>
</tr>
<tr>
<td>Surgical Science</td>
<td>SU spin-off</td>
<td>1997</td>
<td>Medical simulation</td>
<td>13</td>
<td>16.2</td>
</tr>
<tr>
<td>Syspiro Diagnostics</td>
<td>SU spin-off</td>
<td>2007</td>
<td>Neonatal</td>
<td>2</td>
<td>0.1</td>
</tr>
</tbody>
</table>

### Table 4.6  
**Regional firms in the area of Neurological Diseases.**

<table>
<thead>
<tr>
<th>Name of company</th>
<th>USO/CSO Founder</th>
<th>Founded</th>
<th>Main focus</th>
<th>Number of employees</th>
<th>Revenues (MSEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Carlsson Research</td>
<td>USO</td>
<td>2007</td>
<td>Parkinson’s disease, Huntington’s disease</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>Abunon</td>
<td>USO</td>
<td>2009</td>
<td>Alcohol use</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cellartis</td>
<td>USO</td>
<td>2001</td>
<td>Stem cells</td>
<td>50</td>
<td>53.4</td>
</tr>
<tr>
<td>NeuroSearch</td>
<td>USO</td>
<td>1998</td>
<td>Huntington’s disease</td>
<td>34</td>
<td>12.3</td>
</tr>
</tbody>
</table>
### Table 4.7 Regional firms in the area of Cardiovascular and Metabolic Diseases.

<table>
<thead>
<tr>
<th>Name of company</th>
<th>USO/CSO Founder</th>
<th>Founded</th>
<th>Main focus</th>
<th>Number of employees</th>
<th>Revenues (MSEK)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aidera</td>
<td>2004</td>
<td></td>
<td>Insulin measurement software</td>
<td>5</td>
<td>4.8</td>
</tr>
<tr>
<td>Arterion</td>
<td>USO</td>
<td>2007</td>
<td>Artificial blood vessels</td>
<td>3</td>
<td>0.02</td>
</tr>
<tr>
<td>AstraZeneca R&amp;D Mölndal</td>
<td></td>
<td></td>
<td>Cardiovascular, gastrointestinal and respiratory medicines</td>
<td>1 400*</td>
<td>--**</td>
</tr>
<tr>
<td>Cellartis</td>
<td>USO</td>
<td>2001</td>
<td>Stem cells</td>
<td>50</td>
<td>53.4</td>
</tr>
<tr>
<td>Cortendo Invest</td>
<td>USO</td>
<td>1996</td>
<td>Pharmaceutical R&amp;D on the metabolic syndrome</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>DuoCort</td>
<td>USO</td>
<td>1999</td>
<td>Cortisol replacement</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>EveryMed</td>
<td>Entr.</td>
<td>2003</td>
<td>Insulin measurement instrument</td>
<td>6</td>
<td>2.7</td>
</tr>
<tr>
<td>Medfield Diagnostics</td>
<td>USO</td>
<td>2005</td>
<td>Acute stroke treatment</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Procardia</td>
<td>USO (GU Holding)</td>
<td>2008</td>
<td>Risk assessment of CV diseases</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>γ-Graft</td>
<td>USO</td>
<td>2008</td>
<td>Vascular graft</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* It is estimated that that out of this site’s 2 200 employees approximately 1 400 are engaged in research on cardiovascular and metabolic diseases.

** This information is not relevant since this is an R&D site.

The tables confirm that university spin-offs are very common in life science. We can see that for the two areas with the largest number of firms (Biomaterials and Cell Therapy and Medical Signal Processing and Visualisation) more than half of the companies have that kind of origin.

A majority of the companies have been founded after 1990. There are a few older companies, and here one mainly finds the larger ones. Out of the totally 50 companies in the region eight (16%) have been founded during the last five years. All of them are still very small.

In terms of growth during the last years the large firms active in our five focal areas of strength have not to any large extent increased their staff in the region (but some of them have expanded elsewhere). Instead, there are a few other, smaller firms that have grown relatively fast, in terms of employment (see Table 4.8). Three of the four mentioned firms belong to the Biomaterials and Cell Therapy area.³⁴

³⁴ If we look at the entire life science industry in the region, there are two other firms that have grown fast in recent years. It is Breas Medical and Carmel Pharma. The former is a successful manufacturer of home care ventilators and sleep therapy.
Table 4.8  The fastest growing companies.

<table>
<thead>
<tr>
<th>Name of Company</th>
<th>Number of employees 2005</th>
<th>Number of employees 2009</th>
<th>Area of strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellartis</td>
<td>24</td>
<td>50</td>
<td>Biomaterials and Cell Therapy Neurological Diseases</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cardiovascular and Metabolic Diseases</td>
</tr>
<tr>
<td>Cochlear Bone Anchored Solutions</td>
<td>74</td>
<td>134</td>
<td>Biomaterials and Cell Therapy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Medical Signal Processing and Visualisation</td>
</tr>
<tr>
<td>Mentice</td>
<td>5</td>
<td>44</td>
<td>Medical Signal Processing and Visualisation</td>
</tr>
<tr>
<td>Vitrolife</td>
<td>71</td>
<td>119</td>
<td>Biomaterials and Cell Therapy</td>
</tr>
</tbody>
</table>

Figures 4.3 – 4.5 provide graphical illustrations of the size distribution for the five areas of strength (Figure 4.4 includes firms with maximum 250 employees and Figure 4.5 includes firms with maximum 50 employees). Size is here measured both in terms of employment number and revenues. It should be noted that for three of the larger companies (Mölnlycke Health Care, AstraZeneca R&D Mölndal and SCA Incontinence Care) revenues are set at zero, since there is no relevant figure for the regional unit (because the production of developed products takes place elsewhere).

Figure 4.3  Size distribution: all firms.

products. It was acquired by General Electric a couple of years ago. In 2009 it had 63 employees and reached sales amounting to MSEK 251. The latter has successfully developed and commercialised a unique system for handling of toxic drugs. It was recently acquired by Becton Dickinson. In 2009, Carmel Pharma had 96 employees and reached sales amounting to MSEK 284. Becton Dickenson has announced that all activities in Sweden will be closed down.
5 Academic scientific strength

Regional academic research base

As is presented in Table 5.1, the regional number of academic research units and individual researchers (including professors, researchers, PhD students, etc.) varies between the five areas. Note that in this context a "research unit" may be a centre, a department, a division or an individual research group linked to one professor. See Appendix C for a list of the research units covered by this study. The difference in the number of research units, as reported in Table 5.1, is partly a consequence of
how the research is organised within the universities. In some cases several research groups have been brought together in one centre. In other cases the research is more fragmented from an organisational point of view.

Table 5.1  Number of academic research units and researchers in the region.

<table>
<thead>
<tr>
<th></th>
<th>Number of research units</th>
<th>Number of researchers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomaterials and Cell Therapy</td>
<td>13*</td>
<td>184</td>
</tr>
<tr>
<td>Vaccines</td>
<td>1</td>
<td>116</td>
</tr>
<tr>
<td>Medical Signal Processing and Visualisation</td>
<td>5</td>
<td>76</td>
</tr>
<tr>
<td>Neurological Diseases</td>
<td>6</td>
<td>112</td>
</tr>
<tr>
<td>Cardiovascular and Metabolic Diseases</td>
<td>10</td>
<td>248</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>35</strong></td>
<td><strong>736</strong></td>
</tr>
</tbody>
</table>

* Does not include CBR (it conducts stem cell research but belongs to the Neurological Diseases area).

It is within Biomaterials and Cell Therapy and Cardiovascular and Metabolic Diseases where we find the largest agglomerations, with 184 versus 248 researchers respectively. Within the fields of Vaccines versus Neurological Diseases the total number of academic scientists is above hundred individuals (116 vs 112 for the respective areas), while the volume is much less in Medical Signal Processing and Visualisation (76 researchers). It is obvious that the research areas not necessarily are comparable in that they are equally personnel intensive. This implies that what may be considered a ‘critical mass’ of regional scientists varies quite extensively. Nevertheless, within Biomaterials and Cell Therapy and Cardiovascular and Metabolic Diseases there are considerably more people involved on the academic scene, potentially leading to larger possibilities for covering a span of research topics, undertaking large scale projects and making a mark on the national or international arena.

In terms of the number of groups and their sizes one has within the Vaccines area gathered all research groups under one umbrella (the MIVAC centre). Also within the Cardiovascular and Metabolic Diseases area the research activities are to a large extent carried out within larger units, such as for example CMR at Sahlgrenska Academy and the research area Systems Biology at Chalmers. In the other areas the units tend to be smaller and distributed, with Biomaterials and Cell Therapy consisting of as many as 13 individual groups. Generally, the concentration to one organisation has its benefits, including for example ease of attracting the type of financing dedicated to centres of excellence. On the other hand, the number of research groups within a field does not in and of itself denote a more comprehensive or common research profile, or intensive links between individual researchers.

All investigated areas have been relatively successful in attracting external financing for their research activities. In terms of monetary input to each area Figure 5.1 illustrates that especially four of them – Vaccines, Biomaterials and Cell Therapy, Neurological Diseases and Cardiovascular and Metabolic Diseases – have managed to be a magnet for substantive volumes of financing over time.

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Note that internal faculty resources are not included in the display.
If we scrutinise the current (2010) figures for grants per employee, we find that two areas in particular are in the forefront, namely, Vaccines and Neurological Diseases.\textsuperscript{36} We do not have data, however, telling to what extent these numbers are representative of the more long-term pattern.

It is worth highlighting that some of the fields have – in a Swedish comparison – drawn together considerable resources to build substantial groups. Even so, on an international scale, the groups or their financing are not large, and the per-employee measure shows that the average external financing does not amount to the salary cost per individual. Above all, the financial base is not stable over time. Instead, interviews reveal that centre-based financing often is for a limited period of time, and often without universities setting up strategic plans on how to sustain activities long-term.

As regards the scientific output from academic research groups Table 5.2 shows that it is the areas of Neurological Diseases, Biomaterials and Cell Therapy and Cardiovascular and Metabolic Diseases that are most successful. This is true for all the measures of article impact (the global impact of a research unit’s articles), journal impact (the impact of the journals the unit publishes in) and the most cited papers. The world average for article impact and journal impact respectively is 1.0. As a gauge for the article impact one could say that 1.2-1.8 means that the group is significantly better than the world average, 1.8-2.4 it is internationally strong, above 2.4 signifies global excellence. This means that our top three groups could be described as ‘significantly better than the world average’, whereas the less well performing groups are below world average. Importantly, the two regional univer-

\textsuperscript{36} The grants per employee and year are for the respective area in 2010: Biomaterials and Cell Therapy: SEK 265 000; Vaccines: SEK 583 000; Medical Signal Processing and Visualisation: SEK 340 000; Neurological Diseases: SEK 630 000; Cardiovascular and Metabolic Diseases: SEK 246 000.
sities in general (including all scientific fields, not only biomedicine) score around the world average in terms of article impact (Chalmers average: 1.1, University of Gothenburg average: 0.9).

**Table 5.2 Scientific output from academic research groups.**

<table>
<thead>
<tr>
<th></th>
<th>Article impact (Frac MNCS)</th>
<th>Journal impact (JCSm/FCSm)</th>
<th>Is the group represented among the top 5% most cited papers?</th>
<th>Is the group represented among the top 20% most cited papers?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomaterials &amp; Cell therapy</td>
<td>1.38</td>
<td>1.28</td>
<td>Yes (+33%)</td>
<td>Yes (+26%)</td>
</tr>
<tr>
<td>Vaccines</td>
<td>0.86</td>
<td>1.14</td>
<td>No (-36%)</td>
<td>No (-25%)</td>
</tr>
<tr>
<td>Medical Signal Processing &amp; Visualisation</td>
<td>0.65</td>
<td>0.87</td>
<td>No (-88%)</td>
<td>No (-61%)</td>
</tr>
<tr>
<td>Neurological Diseases</td>
<td>1.45</td>
<td>1.26</td>
<td>Yes (+85%)</td>
<td>Yes (+40%)</td>
</tr>
<tr>
<td>Cardiovascular and Metabolic Diseases</td>
<td>1.35</td>
<td>1.32</td>
<td>Yes (+9%)</td>
<td>Yes (+29%)</td>
</tr>
</tbody>
</table>

For the two last columns the percentage signifies percent representation below or above the world average.

We have tried to compare the numbers presented in Table 5.2 with the results from RED10, that is, the University of Gothenburg’s evaluation of its research (University of Gothenburg, 2010). The entities analysed differ between the two studies, which makes the comparison a bit tricky. However, we cannot see that our findings go against the results and conclusions presented in RED10. For example, of relevance to the Biomaterials and Cell Therapy area of strength, Red10 concludes that the Department of Biomaterials is very progressive and has a very good international standing. The research is said to be excellent, even outstanding in some specific fields. The stem cell research, also part of this area of strength, is characterised as “intriguing and promising”. Furthermore, it is concluded that the combination of materials science and stem cell research generates new knowledge, ideas and therapies at the international forefront of regenerative medicine. Also, in regard to Cardiovascular and Metabolic Diseases Red10 concludes that large parts of the research can be characterised as excellent to outstanding. This holds particularly for the groups brought together within CMR. The overall assessment of the university’s neuroscience research points to scientific excellence. Some of the groups are said to have excellent or outstanding quality with high international visibility. As to Vaccines, Red10 concludes that the quality of research conducted within the field of Bacteriology and Immunology is very high by international standards. However, there is a preponderance of papers in journals of lower impact and more limited readership. This may contribute to explain the relatively low numbers for the Vaccines area obtained in our own bibliometric analysis.
Academic research in the area of Medical Signal Processing and Visualisation is to a large extent conducted outside of the University of Gothenburg (i.e., at Chalmers and in Borås). Therefore, no relevant conclusions can be extracted from Red10. There is no corresponding evaluation of the research at Chalmers that we can relate to.

Summary of scientific strength of academic research groups

A recapitulation for each of the fields looks as follows.

Biomaterials & Cell Therapy

- Strong research with good financing and a high level output.
- A fair volume of researchers. We may consider this to be a critical mass of people and activities.
- There are centres of excellence in the region.

Vaccines

- Medium-strong research, with very good financing and medium level publication output.
- Good volume of researchers. It is not clear if this is a high enough volume to be a critical mass of people and activities.
- There are centres of excellence in the region.

Medical Signal processing and Visualisation

- Weaker research, with medium level financing, and weaker publication output than in the other areas analysed.
- A somewhat limited volume of researchers, and not a critical mass of people and activities.
- There are centres of excellence in a related area in the region.

Neurological Diseases

- Strong research with very good financing and high level publication output.
- A good volume of researchers. It is not clear if this is a high enough volume to be a critical mass of people and activities.
- There are centres of excellence in the region.

Cardiovascular and Metabolic Diseases

- Strong research with moderate level of financing and a high scientific output. Especially in the sub-field of diabetes and obesity the research is very strong.
- A large volume of researchers. We may consider this to be a critical mass of people and activities.
- There are several centres of excellence in the region.
6 Clinical practice

This chapter provides some insights into the strength of the region’s healthcare in the five targeted areas. It is Region Västra Götaland (VGR) that has the responsibility for healthcare in the region.\(^37\) This includes Sahlgrenska University Hospital with several sites in Gothenburg and Mölndal. Besides financing of the healthcare services VGR supports research (mainly patient-based) at the university hospital.

The strength of clinical practice, for example in terms of the volume and quality of provided healthcare services in the region, is of importance in several respects. The clinical research, performed by physicians and other personnel who are wholly or partly employed by hospitals, is to a large extent integrated with the clinical operations. Therefore, the strength of the clinical practice affects the conditions for carrying out good clinical research (e.g. access to patients, type and number of interventions, and availability of infrastructure in the form of medical equipment, disease registries and biobanks). How the healthcare is organised and managed is also of importance.

For non-clinical actors – such as pre-clinical and technical researchers and companies – collaboration with the healthcare is often important in order to get valuable knowledge input from clinicians and opportunities to make trials in a clinical setting. Well-performed clinical testing is a prerequisite for successful development of new biomedical products. Especially for small firms, which tend to have scarce resources, it is advantageous to have access to clinical partners locally.

The features of the region’s healthcare system are of importance to all our five areas of strength. Both academic researchers and companies need to interact with clinical practice in their research and innovation activities. The intensity of interaction may, however, differ among the areas. For the two “disease-defined” areas – i.e. Neurological Diseases and Cardiovascular and Metabolic Diseases – we note that much of the research is strongly clinically oriented and well integrated with the corresponding healthcare activities. There are major centres performing basic research, but they seem to have close links with clinical research and clinical practice. CMR, for example, is physically located at Sahlgrenska University Hospital. Within the other three areas of strength (Biomaterials and Cell Therapy, Vaccines, and Medical Signal Processing and Visualisation), due to the nature of the research the linkages to the clinical practice seem to be relatively less intensive. However, as pointed out there is a strong need to involve healthcare also in these areas and there are in fact many examples of collaboration. One of the purposes of MedTech West, for instance, is to facilitate and stimulate collaboration between Chalmers and Sahlgrenska University Hospital (see the historical case in Chapter 3).

In the present study we have not been able, due to time and resource constraints, to make an in-depth analysis of the region’s clinical strength in the five focal areas. Therefore, as the following presentation of collected data shows, it is difficult for us to make more precise statements regarding the effect of clinical practice on the respective area’s development potential.

One variable that may be used as an indicator of strength for a certain area is the number of ongoing clinical studies. We only have data for those studies that are carried out with VGR as principal.\(^38\) All

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\(^{37}\) In most parts of Sweden it is the County Councils which have the corresponding responsibility for the healthcare. The two exceptions are Region Västra Götaland and Region Skåne.

\(^{38}\) Unfortunately, it has not been possible to get the same type of data regarding company-sponsored clinical trials.
together the five focal areas account for approximately 20 percent of the total number of regional clinical studies. This may seem to be low, given the importance of the five areas within the region’s biomedical sector (63% of industrial employment), but this result probably mirrors the breadth of the entire healthcare activities in the region. Out of the 1587 studies being performed (in 2010) 23 are in Biomaterials and Cell Therapy, 38 in Vaccines, 14 in Medical Signal Processing and Visualisation, 60 in Neurological Diseases, and 196 in Cardiovascular and Metabolic Diseases. Thus, we have the highest number of clinical studies in the Cardiovascular and Metabolic Diseases area. This is not surprising since this area is engaging many researchers and is scientifically strong. There are relatively few clinical studies in the areas of Biomaterials and Cell Therapy and Medical Signal Processing and Visualisation. A possible explanation is that given the definition of these areas a larger portion of the research activities is of a non-clinical character (compared to the other three areas).

To make a more qualitative assessment we have in our interviews with various actors in industry and academia asked questions about the interviewees’ view of the clinical practice in the region. Out of this emerges a picture according to which the region in all areas is considered to have clinical strength, for example, in relation to the rest of Sweden. However, as pointed out more hard-type data on the extent and quality of the clinical activities is missing. Thus, there is need for a more thorough analysis in order to get a better picture of the region’s clinical strength in the different areas. Nonetheless, based on what we know we dare to draw the conclusion that the region’s healthcare system (especially relating to Sahlgrenska University Hospital) in all five areas constitutes an important asset that can be used to support the academic research as well as industrial innovation. For example, many interviewees point to the potential for – and need for – more collaboration between the healthcare on one side and industry and universities on the other.

Finally, it can be noted that the region has been awarded national healthcare responsibility in several fields, currently where at least some belong to the cardiovascular area: heart transplantation, epicardio and trans-venous pacemaker implants on children and young adults with inherited heart disorder as well as heart surgery on children and young adults.  

In our discussions with Sahlgrenska University Hospital’s management we have identified some other areas where the region has clinical strength. See Appendix D for a short presentation.

### 7 Regional support schemes

The extent to which the five targeted areas are supported by policy-makers in the region has been studied at three levels: the existence of official policy towards the areas, the extent of current directed support measures, and the involvement of bridging organisations. Our mapping has focused on four major ‘policy actors’: Two public policy organisations – Region Västra Götaland (VGR) and Business Region Göteborg (BRG) – and two universities (University of Gothenburg and Chalmers).

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39 The permission to carry out national healthcare (”rikssjukvård”) is granted by the National Board for Health and Welfare (Socialstyrelsen) to two county councils/regions for a maximum period of five years.

40 The region also has this responsibility for liver and lung transplantation.
The identification of official policy elements pertaining to individual areas of strength builds upon statements made, for example, in strategy documents or on websites or major policy actions manifested for example through directed organisational changes. We have found that for three of the areas there is such an official policy from at least two policy actors (Table 7.1).

### Table 7.1  Current official regional policy towards the individual areas of strength.

<table>
<thead>
<tr>
<th>BRG</th>
<th>VGR</th>
<th>Chalmers</th>
<th>University of Gothenburg</th>
</tr>
</thead>
<tbody>
<tr>
<td>B&amp;CT</td>
<td>GöteborgBIO</td>
<td>GöteborgBIO</td>
<td>GöteborgBIO</td>
</tr>
<tr>
<td>Vaccines</td>
<td></td>
<td></td>
<td>Example of Patient-based research</td>
</tr>
<tr>
<td>MS&amp;V</td>
<td>Visualisation is one of 10 cluster initiatives</td>
<td>MedTech West</td>
<td>MS&amp;V covered by two areas of advance MedTech West</td>
</tr>
<tr>
<td>Neuro</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CVM</td>
<td></td>
<td>Systems biology prioritised in the Life science area of advance</td>
<td>Example of Patient-based research</td>
</tr>
</tbody>
</table>

First, as principals and co-financiers of GöteborgBIO all four policy actors support since 2005 Biomaterials and Cell Therapy, which is at present the only profile area within GöteborgBIO. This is undoubtedly a major and long-term regional policy initiative, which is also supported nationally through Vinnova’s Vinnväxt programme. Each year the Biomaterials and Cell Therapy area receives around SEK 7 million in support from this initiative. Furthermore, at Chalmers, a sub-field within this area termed bionanotech is included in two of Chalmers’ areas of advance (Life science and Materials). In total Chalmers has identified eight such areas which are considered strategic to the university’s development and receive special support.

It should be noted that GöteborgBIO is not exclusively focused on Biomaterials and Cell Therapy. In addition to its profile area GöteborgBIO supports biomedicine in general, and this of course includes the other four areas of strength. While the profile area has received for each year some SEK 7-8 million in dedicated support (incl. in-kind contributions), fully SEK 15 million annually have been spent on biomedicine in general.

Second, Medical Signal Processing and Visualisation is another area of strength which is officially backed by all four policy actors. Starting a couple of years ago, VGR, Sahlgrenska University Hospital, Chalmers, University of Gothenburg and University of Borås jointly support the network organisation MedTech West. Its mission is to stimulate regional research as well as innovation in the medical technology field – not least by facilitating collaboration between Chalmers and the university.

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41 The annual support from VGR amounts to approximately SEK 1.5 million.
hospital. One of the driving actors behind this initiative is the Division of Biomedical Engineering at Chalmers for which signal processing is a key research area. Chalmers also supports this area of strength through two of its areas of advance – Life science and ICT respectively. BRG is not involved in MedTech West but instead supports, together with Chalmers, the area through one of its cluster initiatives, which is visualisation. The cluster is broadly defined from a technical and application point of view, but healthcare is chosen as one of the targeted application fields.

Third, the **Cardiovascular and Metabolic Diseases** area also receives support in different ways from several regional policy actors. At Chalmers, systems biology is a prioritised research field within the life science area of advance and significant resources have been invested in creating an internationally strong research environment. Today, the research is increasingly focused on metabolism and partly carried out in collaboration with the Sahlgrenska Centre for Cardiovascular and Metabolic Research (CMR) at the University of Gothenburg. That is why Chalmers’ strategic efforts in the field of systems biology can be seen as support of the Cardiovascular and Metabolic Diseases area. At the University of Gothenburg, patient-based research is identified as a core research area and in its strategy report for 2009-2012 diabetes and obesity is mentioned as one example (University of Gothenburg, 2008).

In **Neurological Diseases** and **Vaccines** we cannot see that the region at present has an official policy for these specific areas. It is true that the University of Gothenburg in its strategy report (ibid.) mentions Vaccines as another example of patient-based research. But that is basically what we have found in terms of current official policy directed specifically at the two areas. However, it must be remembered that both Neurological Diseases and Vaccines are subject to support through the general policy for biomedicine. All the four key policy actors covered in this report have designated biomedicine, or life science more broadly, as a priority area.

As to VGR, it is formally involved in GöteborgBIO and MedTech West. Apart from that it does not have any explicit research policy directed at any of the analysed five areas of strength, or at any other healthcare field. However, VGR is a major financier of research carried out at the university hospital. It supports research by distributing government money (so-called ALF grants), by giving own grants, and by placing at disposal the healthcare infrastructure needed for clinical research (i.e., facilities, competent staff and patients). Out of VGR’s annual research expenditures amounting to approximately SEK 1 billion ALF accounts for some SEK 350 million. There are some SEK 25 million in other grants. Thus, the largest part of VGR’s research support (around SEK 600 million) consists of the costs for the healthcare platform which is provided for free as a form of “counter funding” linked to ALF projects and other research projects funded by the university. This includes co-funding of some 30 professorships and some 75 adjunct professorships.

It is important to note that VGR does not want to have a policy which means that certain fields of research are prioritised (e.g. for political reasons). Instead, VGR makes its research efforts in collaboration with the University of Gothenburg and relies on the quality assessment made by the university. That is, it supports high-quality research. In practice, this also means that those research fields that receive most support from the university also receive most support from VGR. One

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It might be worth mentioning that some years ago VGR supported the creation of the Arvid Carlsson Institute at the University of Gothenburg, which was focused on the neuro area. The present Centre for Brain Repair and Rehabilitation (CBR) has its origin in this institute, but is currently not receiving any special support from VGR.
example is diabetes and obesity, which is an important part of the Cardiovascular and Metabolic Diseases area. Diabetes and obesity is a large disease group and in addition Gothenburg has since long strong research carried out by several groups. CMR is, for example, a big receiver of support from VGR (e.g. in the form of free rent for facilities).[^43]

On the second level of analysis we have tried to identify, irrespective of the existence of an official policy, concrete support measures that are currently directed at the five areas of strength. The most important measures that we have found are shown in Table 7.2. Here we have included ALF grants from VGR for the whole period 2000-2013 (i.e. the same numbers used in our financing analysis).

Otherwise, we have not included support measures taken in the past (e.g. start-up contributions given to certain research centres). Nor is VGR’s above-mentioned counter financing of research included (since we do not have information about how these resources are distributed across areas).

<table>
<thead>
<tr>
<th>Table 7.2</th>
<th>Current directed support measures.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BRG</strong></td>
<td><strong>VGR</strong></td>
</tr>
<tr>
<td>B&amp;CT</td>
<td>Funding of GöteborgBIO</td>
</tr>
<tr>
<td></td>
<td>Funding of Biomatcell</td>
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<tr>
<td></td>
<td>ALF: MSEK 45</td>
</tr>
<tr>
<td>Vaccines</td>
<td>Funding of commercialisation platform</td>
</tr>
<tr>
<td>MS&amp;V</td>
<td>Funding of CVG</td>
</tr>
<tr>
<td></td>
<td>ALF: MSEK 66</td>
</tr>
<tr>
<td>Neuro</td>
<td>ALF:[^44]</td>
</tr>
<tr>
<td>CVM</td>
<td>ALF: MSEK 144</td>
</tr>
</tbody>
</table>

Most of the measures mentioned in Table 7.2, usually in the form of various types of grants or other types of funding, are consequences of the official policy identified above. One example is the Center for Visualization Göteborg (CVG), which is a result of BRG’s cluster initiative (see Table 7.1).

There are also other directed efforts made by the policy actors. For example, despite the lack of an official policy towards the area, commercialisation of the vaccine research is supported both by VGR and the University of Gothenburg.

[^43]: The creation of the Arvid Carlsson Institute for neurological research is an example of a directed investment in the past. VGR’s current policy is to not engage in this type of isolated efforts. Instead, it prefers to support research units which are well-integrated in the university organisation.

[^44]: We estimate this to be in the range of MSEK 50-60.
It should also be noted that all areas have received support through general support schemes directed at the whole biomedical area. This includes for example GöteborgBIO-financed GIBBS projects and verification grants distributed through Sahlgrenska Science Park. The three vaccine-based business projects mentioned previously have all started in GIBBS. One of them has now been transferred to Sahlgrenska Science Park’s incubator, which is partly financed by GöteborgBIO.

On the third level of analysis, we have looked into the involvement of bridging organisations in the five areas of strength. Figures 7.1-7.5 show individual firms and academic units that currently receive support from various bridging organisations. It can be, for example, in the form of grants, seed financing, premises, or coaching. We have also included in the figures, with dotted lines, firms and units which have received some kind of support from such organisations during the past 5-6 years. Examples of this are firms that have received verification grants from Sahlgrenska Science Park, have belonged to an incubator or science park and left, or have been established within the GIBBS school of entrepreneurship (now part of G4E).

**Figure 7.1  Bridging organisations involved in the Biomaterials and Cell Therapy area.**
Figure 7.2  Bridging organisations involved in the Vaccines area.

GöteborgBIO

| Sahlgrenska Science Park |
| Simplexia |
| Auremune |
| Traccine Pharmaceuticals |
| MIVAC Development |

GU Holding

| Innovations-bron Väst |
| Immunicum |

Chalmers Innovation

Figure 7.3  Bridging organisations involved in the Medical Signal Processing and Visualisation area.

MedTech West

| Medical Engineering/Borås Univ. |
| Biomedical Engineering/Chalmers |
| Radiation Physics/SA |
| Clinical Neuroscience/SA |
| Qualisys |
| MedNet/SA |

CVG

Microwave Road

| Medfield Diagnostics |
| Sahlgrenska Science Park |
| G4E/Encubator |
| Syspiro Diagnostics |

Chalmers Innovation

| Micropos Medical |
We can see that bridging organisations are quite active in three of the areas, namely, Biomaterials and Cell Therapy, Medical Signal Processing and Visualisation, and Cardiovascular and Metabolic Diseases. The Vaccines area also receives some support despite the almost non-existing industry. It is noteworthy that the Neurological Diseases area, for some reason, has not managed to catch the attention of these organisations. Their involvement in this area is very limited.

To summarise, a relatively clear picture is emerging from this analysis of the regional support schemes. As we have seen, the key policy actors are in different ways engaged primarily in three of the areas. The two others, that is Vaccines and Neurological Diseases, are not subject to the same amount of support.
8 Regional networks and collaborations

As a gauge of regional knowledge exchange and ongoing joint learning processes we have mapped the extent to which regional actors relate to one another, exchange resources or collaborate. Figures 8.1 – 8.5 illustrate some of the currently most important regional collaborative relationships in each of the fields.

The existence of regional collaboration and networks among different “actors” – such as firms, academic research groups, healthcare units, authorities and public support organisations – is an important feature of a region which affects the possibilities for innovation.45 In our interviews with company representatives and research leaders we have therefore asked questions about ongoing collaborations, especially with other regional actors. Based on these data we have made for each area of strength a picture of the regional network which covers industry, academia and healthcare. In the figures we have chosen to place clinical research units/groups in the category of Healthcare. There is an overlap between healthcare and academia, since clinical research is often carried out by departments or divisions that are physically located at the university hospital. Many professors have dual positions where they are employed both by the university (i.e. Sahlgrenska Academy) and by the hospital. The category of Academia thus comprises all other research, that is for example, basic, experimental, pre-clinical and technical. Some units/groups may be involved in both clinical and other research. Therefore, the categorisation of individual actors is in reality somewhat arbitrary.46

The main point with these pictures is to give the reader, for the purpose of comparison, an overall impression of what characterises the different areas from a networking point of view, rather than using them to study details. For methodological reasons these pictures have certain limitations which should be borne in mind when interpreting them. First, we have tried to catch only the most important relationships, but we may have missed even some of them. Second, the figures do not make any difference between relationships – all arrows look the same. In reality, there are of course differences with regard to for example the character and purpose of the collaboration, the intensity of interaction, the importance, and whether the relationship is long-term or not. Third, the figures show currently ongoing collaborations and therefore do not say anything about the dynamics and the history. Relationships tend to develop over time. We know, for example, that certain relationships which have been important in the past are not active at present (and therefore not shown in the figures). Such knowledge is of course important when analysing networks. Fourth, we have chosen to not include important relationships to actors situated outside the region. We have some information about such relationships but it is far from being complete. Despite these reservations we believe that the image given by these figures contribute to our understanding of each area and the analysis of their development potential, which we will come back to in the next chapter.

45 See for example Laage-Hellman et al (2007) which describes networking patterns from the perspective of biomedical firms in Western Sweden.
46 It can be noted that to the industrial partners it is not always clear whether they have a collaborative relationship with the hospital, as a healthcare provider, or with the university.
**Figure 8.1** Regional network for Biomaterials and Cell Therapy.

**Figure 8.2** Regional network for Vaccines.
Let us start by commenting the *Biomaterials and Cell Therapy* network (Figure 8.1). It illustrates what was concluded already in Chapter 4 on industrial activities, namely that in this area we have a true cluster. There are many actors of different kinds, including for example large as well as small firms, various research groups both from the medical and technical side and various clinics. Moreover, there are many connections both within the industry and between firms and research or healthcare units. Thus, there is a great deal of collaboration going on within the network.

One typical feature of a cluster is that we have competition among firms. In this case, both Nobel Biocare and Astra Tech are among the world’s largest suppliers of dental implants and these two firms compete intensely with each other on the global market. Besides them there is at least one small firm which has more recently entered the field (Neoss). Furthermore, within the sub-field of bone-anchored hearing aids there are two firms – Cochlear Bone Anchored Solutions and Oticon Medical. The first one is the innovator and pioneer and the second one is a follower.

An important observation is that several of the key players in this cluster are foreign-owned companies. Astra Tech belongs to a large international corporation, AstraZeneca.\(^{47}\) Nobel Biocare was founded as a Swedish firm but it is now controlled by foreign investors. Cochlear Bone Anchored Solutions has its origin in a spin-off from Nobel Biocare, which was later acquired by the Australian

\(^{47}\) As mentioned, AstraZeneca has announced a deal to sell Astra Tech to the American firm DENTSPLY International.
company Cochlear. Oticon Medical is a subsidiary of Oticon A/S, a large hearing aids company in Denmark, which bought a small start-up. Neoss is the subsidiary of a UK-based firm.

Figure 8.4 Regional network for Neurological Diseases

The Vaccines network (Figure 8.2) looks very differently. The number of actors is very small, even if we include the three business projects, and there is not much collaboration among regional actors. In other words, there is no vaccine cluster. It can be added that also in other parts of Sweden the vaccine industry is weak.¹⁴⁸

In Medical Signal Processing and Visualisation, the network is more developed but far from being as dense as in Biomaterials and Cell Therapy (Figure 8.3). There are a reasonably large number of actors and collaborative relationships. Some of the latter are of a relatively recent date and the result of conscious initiatives to increase networking within the region (e.g. MedTech West). We will come back to this observation in the next chapter on development potential.

The Neurological Diseases network is illustrated in Figure 8.4. There are few industrial actors – only two firms that are fully dedicated to the area. Cellartis, a stem cell company, is included because it is working on neuro applications in one collaborative project with the Centre for Brain Repair and Rehabilitation (CBR). It is interesting to note that NeuroSearch is originally a spin-off from the University of Gothenburg, but today it has no relationship with the founding department. Instead it has a

¹⁴⁸ The global market for vaccines is highly concentrated and dominated by five large pharmaceutical companies.
fruitful collaboration with the university hospital for the purpose of clinical trials. That is one of the reasons why this company likes to stay in the region despite being a subsidiary of a Danish firm.

**Figure 8.5 Regional network for Cardiovascular and Metabolic Diseases**

In the Cardiovascular and Metabolic Diseases area, the network is relatively sparse (Figure 8.5). The industry is dominated by one big actor – AstraZeneca R&D Mölndal. There are a number of smaller firms. Several of them are spin-offs from Chalmers or from the University of Gothenburg, and they often have collaboration with their parent institutions and sometimes also with other academic research groups in Gothenburg. The largest of these university spin-offs is Cellartis (a key player also in the biomaterials and cell therapy network). Cellartis is since several years collaborating on cardiac stem cells with AstraZeneca and one of the clinical research groups at Sahlgrenska University Hospital (it belongs to the Department of Clinical Chemistry and Transfusion Medicine at Sahlgrenska Academy). Otherwise, AstraZeneca does not have any collaboration with other firms in the regional network in this area.

On the academic side, AstraZeneca has a close collaborative relationship with several groups at the Sahlgrenska Centre for Cardiovascular and Metabolic Research (CMR), which is carrying out primarily basic research. There are also some collaboration, exchanges and contacts with other research groups, pre-clinical as well as clinical, within Sahlgrenska Academy and Sahlgrenska University Hospital. This includes, as illustrated in Figure 8.5, several groups which belong to the Institute of Medi-

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49 For further information on this collaborative project see Laage-Hellman et al (2009).
Generally speaking, however, apart from CMR AstraZeneca’s research collaboration with regional partners is not extensive today. This situation can be contrasted with the historical pattern. In the past (i.e. mainly before the merger between Astra and Zeneca in 1999), the Mölndal site had a very close and fruitful collaboration with several clinics at the university hospital, and several of the company’s largest cardiovascular products have their origin in regional collaborations. An important case in point is the use of betablockers for treatment of heart failure, where researchers from the cardiology clinic played a key role. However, in more recent times the clinical collaboration has decreased for a variety of reasons, related to changes both within the company (e.g. changing prioritisations in R&D; recruitments of new people with different – i.e. more global – contact networks; and increasing bureaucracy and secrecy triggered by the growth of the company) and in the healthcare system (e.g. less time for physicians to do clinical research). However, AstraZeneca is now in the process of intensifying external research collaboration, as one means to boost R&D productivity. In line with this increasing openness representatives of the Mölndal site express an interest in establishing closer clinical collaboration with regional partners, and also in expanding academic collaboration in the region more generally (e.g., by jointly developing new technical platforms that can be used by both parties).

Regarding the internal networking within Sahlgrenska Academy and the university hospital, in the area of cardiovascular and Metabolic Diseases, we can refer to the University of Gothenburg’s recent evaluation of its research (University of Gothenburg, 2010). Panel 14 on Medicine points out that there are several strong groups in the cardiovascular field and that they have close collaboration with relevant clinical sections. However, it also concludes that the clinical research tends to be fragmented and is characterised by poor interaction between the groups. By contrast, CMR is judged to have been successful in promoting interaction between independent research groups.

Generally, it is clear that a dense regional network may point to regional strength in the form of, *inter alia*, ongoing inter-organisational learning processes, pooling of complementary resources, synergistic effects, and staff mobility. Thus, we conclude that the existence of a well-developed network in a certain area positively affects the potential for industrial development, cluster-building and economic growth in that area.

Before turning to this issue in the next chapter, we can note that several of the policy initiatives, such as GöteborgBIO and MedTech West, aim at supporting collaboration and network-building – both intra- and inter-regionally. The existing networks, illustrated in this report, have emerged naturally as a result of the actors’ own contact-seeking and interacting activities. These are, however, processes that can be stimulated and facilitated by policy-makers. In the area of Biomaterials and Cell Therapy, for example, there is no doubt that GöteborgBIO has contributed to make the network somewhat more dense than it would otherwise be. These effects have come through multilateral R&D projects, verification grants enabling the receivers to establish new relationships, and by providing meeting places where regional actors can discover and explore common interests. The VinnExcellence centre Biomatcell seems to have had similar effects. In addition to increasing regional collaboration this centre has also helped regional actors to build up new relationships outside the region – especially with companies (e.g. Sandvik and Bactiguard).
9 Development potential of investigated areas of strength

Based on the analysis presented in preceding chapters we conclude that all five areas investigated have certain strengths, but these vary in character and magnitude and give varying potential for industrial development and economic growth in the short and medium term. In this chapter, the development potential will be discussed for each area. Our main conclusions, which will be elaborated in the following sections, are summarised in Table 9.1.

Table 9.1 Development potential for investigated areas of strength.

<table>
<thead>
<tr>
<th>Area</th>
<th>Development potential</th>
</tr>
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</table>
| Biomaterials and Cell Therapy             | • Further development of existing cluster  
• Linking of biomaterials and cell therapy                                              |
| Vaccines                                  | • No basis for cluster formation  
• Maintain research strength in current niche  
• Opportunity to commercialise research through licensing/start-ups                      |
| Medical Signal Processing and Visualisation| • Potential for research-based industrial development  
• Opportunity to use the new Imaging and Intervention Centre for innovation procurement and industrial development  
• Opportunity to benefit from development in other (non-medical) application fields |
| Neurological Diseases                     | • No basis for cluster formation  
• Potential for more university spin-offs                                               |
| Cardiovascular and Metabolic Diseases     | • Potential for more university spin-offs  
• Further strengthening of dominant firm (AstraZeneca)  
• Re-establishment of clinical collaboration between AstraZeneca and the healthcare system  
• Potential for corporate spin-offs  
• Potential to start cluster-building process  
• Potential to strengthen the academic research |

Biomaterials and Cell Therapy

As we have seen, we have here already today an existing cluster of firms with considerable strength, even from an international perspective. In addition to the industrial strength, the academic research is characterised by good volume, successful funding and a high level of scientific output. Moreover, this area is currently receiving, compared to other biomedical areas, relatively strong support from the regional policy actors. In our view, based on these positive factors there is a very good potential for continued development of the industry, both in terms of new innovations and economic growth. This holds for those sub-fields where the region is particularly strong already – that is primarily dental implants and bone-anchored hearing aids – as well as for new emerging sub-fields, e.g. in tissue engineering and regenerative medicine (TERM). With a few exceptions, the regional firms are currently not so active in the latter fields. But the high-quality research in the region, which is increasingly directed towards TERM, in combination with existing competencies and resources in the firms
create opportunities to build successful businesses also in these new fields of application. We would therefore argue that the regional policy actors have good reasons to continue supporting the area.

A related opportunity for scientific and industrial development is linking of the more traditional biomaterials technology (e.g. osseointegration) with the emerging new technologies in the field of cell therapy. Such attempts are already going on within the Biomatcell centre of excellence.

Regarding TERM, Rickne and Sandström (2007) conclude that Sweden as a small country cannot become a world-leader neither in research nor in industry. Nonetheless, Swedish players can build strong positions in sub-fields, but this probably requires increasing research investments in certain scientific areas where Sweden is currently weak – such as matrices and scaffolds, ceramics, and biomimetics. Given for example the multi- and inter-disciplinarity of TERM the authors also point to the importance of clustering. That is, knowledge-sharing, collaboration and mobility among co-located actors create favourable conditions for fruitful commercialisation. At the same time, successful industrial development, in a Swedish context, requires collaboration among the TERM-related research and innovation environments that exist in different parts of Sweden as well as building of strong links to foreign centres of excellence. Given the present situation and development trends in the Biomaterials and Cell Therapy area, as described in this report, it must be concluded that Gothenburg has a good chance to become a leading node in the Swedish network of TERM-related research and innovation environments. However, in order to make this happen continued efforts to strengthen and broaden the region’s scientific knowledge base and to support commercialisation activities are necessary.

**Vaccines**

In the Vaccines area, the industry is very small and we cannot see that there is, at least not in a foreseeable future, any potential for cluster formation. The region’s industrial base is thus very weak. In addition, the vaccine industry is generally characterised by high concentration and is globally dominated by a small number of multinational firms.

The region is home to a major research centre, MIVAC, which is doing good research in specialised sub-fields (mucosal vaccines and adjuvants). With continued support from national and/or regional research financiers it is possible, of course, to maintain a strong scientific position within these niches. A possible threat to this scenario, however, is that several key persons are about to retire in a relatively near future. Needless to say, it is important that appropriate succession is secured if the position shall be maintained.

To the extent that the academic research at MIVAC generates results with a commercial potential, these opportunities can of course be exploited – for example by licensing to existing vaccine companies or by starting up new firms. Such activities are already under way through MIVAC Development, a company created for this purpose with support of GU Holding and VGR. We have seen that commercialisation opportunities in the Vaccines area have come up also from other medical research environments (the three business projects mentioned earlier). Such ventures can be supported through the general support schemes directed at biomedicine in general (e.g. GIBBS and incubators).

Properly supported commercialisation activities in the Vaccines area may lead to the formation of new companies in the region, but as mentioned it is not likely that this would lead to the emergence
of something that can be called a cluster. Still, there can be some other positive effects for the region, such as some new industrial employment and inflow of capital from licensing – money that, e.g., can be invested in new projects. The presence of regional vaccine companies may also have a positive impact on the research by facilitating closer links between academic and industrial activities. In the longer run, such links may help researchers to do better science and also increase the probability for emergence of findings with commercial potential.

Medical Signal Processing and Visualisation

In this area of strength, compared to the previous one, we see that there are better chances for industrial development, for example linked to the region’s research. It is true that the academic research is not as strong as within some of the other areas. But the research, for example at Chalmers, is now expanding with support of Region Västra Götaland among others. There are scientific leaders who are dedicated to innovation and now receive active support from several policy actors through the initiative MedTech West. There seems to be a trend towards increasing collaboration within the region, and also with actors outside the region.  

The industrial base is not large at present. Most firms are quite small and there is no big company. The historical track record for commercialisation of the region’s research is disappointing from a regional perspective. Yet, given the above mentioned trends and assuming continued support from the region, we believe that this area may offer an opportunity for long-term industrial development.

This conclusion is partly founded on the existence of two other development possibilities that we have identified. First, the building of a new Imaging and Intervention Centre at Sahlgrenska University Hospital opens up opportunities for innovation procurement. This is a major investment making it possible to introduce the latest technologies and develop new ones in co-operation with suppliers of medical equipment. If the possibilities for innovation procurement are taken advantage of and at least to some extent are directed at local firms this may contribute to spur industrial development within the region.

Second, there are possibilities that development of medical applications can draw on research and technological development with a broader scope. Solutions for signal processing and visualisation are used by other (i.e. non-medical) industries. There are in the region several large companies active in the field through their own R&D and collaborations with Chalmers (e.g. Ericsson, RUAG Space and Volvo). Regional medtech firms may thus draw on these developments, for example, by participating in the BRG-supported cluster for visualisation.

Finally, it might be worthwhile to mention that there is in Gothenburg a great deal of other research on information and communications technology (ICT) some of which has relevance for the development of medtech products. Especially, if one considers broadening the definition of the area to cover all types of ICT-related medtech products this type of research would be important to include in future mapping activities.

50 For example, researchers at Chalmers are trying to establish closer links with leading medtech companies located in other parts of Sweden.
51 For example, pioneering research in the field of telemedicine has been commercialised, but the company (Ortivus Medical) is situated in Stockholm.
52 See Copenhagen Economics (2009) for a general discussion on the possibilities for innovation procurement in healthcare.
53 At present there is only one medtech company involved in this cluster initiative and that is Qualisys.
**Neurological Diseases**

In the Neurological Diseases area the industry is small, consisting basically of two firms fully dedicated to the area and one partly involved. Therefore, like for vaccines, there is no basis for building a cluster. However, as shown in Chapter 5 the academic research is strong and the scientific output is internationally competitive. Without having detailed knowledge about the nature of this research we assume that there may be a potential for new firm formation based on research findings (or other commercialisation alternatives).\(^{54}\) Again, such spin-off activities would be positive from an industrial development point of view, but they would hardly be enough to create a cluster.

It seems that at present there is no regional policy dedicated to the Neurological Diseases area. We assume that more directed support measures might be needed if the alleged spin-off opportunities will be created and exploited.

**Cardiovascular and Metabolic Diseases**

Cardiovascular and Metabolic Diseases is another area where the region’s academic research is strong. At the same time, the number of firms is quite limited. Similarly as in the Neurological Diseases area we may therefore postulate that there are so far unexploited opportunities for more university spin-offs. We note that GU Holding, through Procardia, supports a commercialisation initiative at CMR.\(^{55}\) However, we think that more dedicated efforts might be needed to stimulate firm formation in the area.

More important from a growth point of view further development of the dominant firm, i.e. AstraZeneca’s R&D site in Mölndal, offers interesting opportunities for the region. It goes without saying that the success of this site’s R&D activities in the area of Cardiovascular and Metabolic Diseases has a huge impact on the development of this site as well as on the employment in the region’s life science sector. The degree of success, in terms of new product innovations, is of course mainly dependent on firm-internal factors. Despite this, the region’s policy actors have strong reasons to facilitate for the company to carry out its R&D activities in the region. One area where there is room for major improvements is the collaboration between AstraZeneca’s Mölndal site and the university hospital (including clinical practise as well as clinical research linked to Sahlgrenska Academy). We believe that re-establishing closer collaboration between the two research environments offers interesting opportunities for regionally-based innovation in the area.\(^{56}\) For this to happen more openness and commitment is required on both sides.

The Mölndal site is primarily an R&D facility. Therefore, if it succeeds to develop new products the production and other commercial activities will be carried out elsewhere within the AstraZeneca Group. In other words, most of the growth effects will take place outside the region. But this does not mean that the region will be left without any share. Successful R&D in the area of Cardiovascular and Metabolic Diseases may lead to expansion of such research. In addition to that, high performan-

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\(^{54}\) In order to make a more reliable assessment of the spin-off possibilities more detailed knowledge about the research and its character would be needed.

\(^{55}\) Procardia is a company which offers risk assessments for cardiovascular diseases. The service can be offered as an integrated part of health check-ups.

\(^{56}\) In our interviews we have come across some potentially fruitful links that are missing today.
ce will strengthen the site’s competitive position within the group and make it more attractive for other investments.\textsuperscript{57}

We would also like to point to the possible potential for corporate spin-offs from AstraZeneca. In the gastro-intestinal field some research activities in Mölndal were spun off a couple of years ago and formed the basis for a new company – Albireo. This seems to be, at least so far, a positive event from a regional point of view. The question we would like to raise is if there may be similar opportunities in the Cardiovascular and Metabolic Diseases area. This is difficult to know, but if so corporate spin-offs from AstraZeneca would contribute to vitalise the regional network in the area.

Another somewhat related question that can be raised is if there is a potential to build up, in the longer term, some kind of cluster in this area. In the present situation the industry is totally dominated by one firm. There are a few others, but they are small and do not seem to be part of a tight regional network. But AstraZeneca Mölndal is not only interested in increasing collaboration with the universities and the university hospital. AstraZeneca would also welcome an increasing number of regional firms active in the area. First, this might provide opportunities for collaboration with small R&D-based companies with interesting technologies. Second, it would create increasing mobility of people. It seems that compared to the Vaccines and Neurological Diseases areas, where we also have at present a limited number of regional firms and good academic research, this area offers better opportunities to start a cluster-building process. But this must then be seen as a long-term undertaking, where AstraZeneca and the regional policy actors join forces and stimulate industrial development by starting up new firms or attracting existing ones to move in from outside the region.

Finally, we would like to point to the possibility to further strengthen the academic research base, which also could have long-term positive effects on the industrial development in the region. Today, within the area of Cardiovascular and Metabolic Diseases the region has strong academic research especially in the sub-field of diabetes and obesity (sizable research units and internationally competitive scientific output). In other sub-fields the picture is more divided. There is considerable strength in some niches, such as heart failure and cardiovascular epidemiology. In many other parts of the broad clinical cardiovascular research area the region has no particular strength or may even be lagging behind other universities in Sweden.

Historically, however, as described in Chapter 3 Gothenburg has had a very strong and successful cardiovascular research – in many respects world-leading. For a variety of reasons this position started to decline during the 1990s. What now remain from this golden era (1970s-1990s) are a few niches where Gothenburg is still in the international forefront (especially heart failure and cardiovascular epidemiology). After having lost much of its leading position it seems that the cardiovascular research since a few years is regaining strength. Not least, thanks to the formation of CMR there is today a large and strong centre focusing on basic research (not only working on diabetes and obesity). Furthermore, on the clinical side several new and expanding research groups have been formed. The creation of new professorships in the area shows that the University of Gothenburg actively supports the field. Our interviews with research leaders indicate that there are potential

\textsuperscript{57} One current example is stem cell research. Thanks to successful R&D activities carried out in Mölndal partly in cooperation with regional partners – both within industry and academia – Mölndal has emerged as an important node in AstraZeneca’s stem cell efforts (Laage-Hellman et al, 2009).
development opportunities in the area. Registry research constitutes one such opportunity. Generally, the prerequisites for conducting such research are good in this region thanks to its size (1.6 million inhabitants) in combination with a well integrated healthcare. In addition, VGR invests in clinical research more than other regions/county councils in Sweden. VGR’s establishment of Gothia Forum is expected, *inter alia*, to boost the number of clinical trials carried out in the region. It is also worth mentioning that Sahlgrenska University Hospital has appointed a director for research and education. It is currently a professor of cardiology. More important, the cardiovascular field is seen as one of the hospital’s areas of strength, where there are intentions to link increasing research efforts to the clinical practice. All this creates favourable conditions to strengthen the cardiovascular research. Whether this opportunity will be taken advantage of or not depends of course to a large extent on the researchers themselves. It remains to be seen if the academic leadership is strong enough to allow Gothenburg to recapture its leading position within the broad area of cardiovascular research. For this to happen sustainable support from the main policy actors is also necessary.

**Summarising comment**

In this chapter we have identified the development potential for each area of strength – as we see it based on the analysis presented in Chapters 4-8. We have also in some cases hinted at possible policy implications. However, it is not our task in this report to suggest what policy that regional actors should adopt in each area. Instead, it is the responsibility of the policy actors to develop and implement their strategies on the basis of the results from this study and other input and considerations.

Nonetheless, before proceeding to some general conclusions we would like to bring out the obvious strength of two areas, namely, Biomaterials and Cell Therapy and Cardiovascular and Metabolic Diseases. They are strong both from an academic and industrial point of view and they also receive a great deal of support from regional policy actors. In our opinion they must be seen as strong candidates to be selected as profile areas for GöteborgBIO. The former is currently a profile area and the latter was a profile area during the first period of GöteborgBIO.

The area of Medical Signal Processing and Visualisation does not exhibit the same strength and is therefore not an obvious candidate. However, there are certain reasons why this area should be considered. Several regional policy actors already support the area and regard it to be important to the future development of the healthcare system. Furthermore, there seem to be good opportunities to link the area to other regional activities – in academia, industry, and healthcare – and this can be expected to have positive effects on the development. One possibility, to make the area more attractive, is to broaden its definition – compared to how this is done in the present study – and include, for example, other IT- and electronics-related activities of relevance to healthcare applications.

As to Vaccines and Neurological Diseases, it is harder to see why they should be selected as profile areas in their own right. Both have, as we have seen, certain strengths. At the same time, there are also significant weaknesses, not least with regard to the existing industrial base. Under all circumstances, these areas can be supported through the general support schemes used by GöteborgBIO. In addition, there is an overlap between areas that Vaccines and Neurological Diseases can benefit from. It means that certain projects or companies may receive support dedicated to other areas of strength. For example, there is ongoing stem cell research focusing on the brain. As another examp-
le, stroke is one of the diseases dealt with in the cardiovascular research as well as within the area of Medical Signal Processing and Visualisation.

10 General conclusions

In this final chapter we will outline some general conclusions under the following headings:

- Regional strategies for each area of strength
- National lead in development of Swedish strategy
- Regional networks and collaboration
- Scientific leadership
- Early-phase commercialisation

We believe that these conclusions are relevant to take into consideration in the policy-making process. They are based primarily on data that we have obtained through the interviews but they are also to some extent affected by insights that we have gained through other studies in the region.

Regional strategies for each area of strength
We suggest that for each area of strength the key actors come together and discuss how the area could and should be developed and supported in order to exploit identified opportunities. All types of regional actors – from academia, industry, healthcare, support organisations and policy – should be involved in this process. The goal should be to build a common vision about the future and a joint regional strategy.

It is our belief that bridging organisations, such as those mentioned in Chapter 7, have a central role to play, both in the strategy formulation process and in the subsequent implementation phase.

National lead in development of Swedish strategy
In some of the areas there is a possibility for the region to take a lead in discussing and formulating a strategy at the national level. This is definitely the case for the area Biomaterials and Cell Therapy. We have seen that in this area the region has strengths in all dimensions of analysis. There are strong research groups as well as a fairly large number of successful companies. The regional actors in many cases also have good connections to other important actors in Sweden. The region is therefore in a good position to become a national competence and coordination node. The organising of, for example, hearings and workshops could be a suitable start of the strategy formulation process.

Possibly, a similar coordination initiative can be taken in the area of Cardiovascular and Metabolic diseases. This is a broad field so maybe the activities should be limited to certain sub-fields where the region is particularly strong. Diabetes and obesity could be one such example.

In the other three areas, the region has certain strengths but we cannot see that there is the same potential to play a leading role nationally. However, active participation in such a process, if driven by others, is of course possible and should be encouraged.58

58 As an example of a national coordination initiative from another biomedical sub-field, it can be mentioned that in radiotherapy a small group of people from state-owned financing companies are trying to create a collaboration network among Swedish firms. Both large and small firms are involved (including one small company from Gothenburg). This is an initiative currently limited to industry, but it illustrates an interesting attempt to gather actors from different parts of
Regional networks and collaboration

The regional networks and collaboration patterns described for each area in Chapter 8 should be retained and strengthened. By doing so, new development opportunities can be created, for example, by bringing together complementary resources and activities. Successful R&D collaboration and related commercialisation activities often require closeness between collaborating partners and geographical proximity is therefore an advantage. To facilitate regional networking, the region should provide different types of arenas for interaction. It can be workshops on specific themes of interest to several firms and multilateral R&D projects.

Regional networking should not, however, be seen as a substitute for inter-regional collaboration with partners in other parts of Sweden or abroad. Such links also need to be further developed and support schemes may be needed also for this purpose. For example, within the area of biomaterials, joint efforts between regional actors have been made to map and diffuse awareness of current networks, as well as to form strategies for future network links (Rickne et al. 2010). Note that strong networks within the region contribute to making the region more attractive to extra-regional actors (for collaboration and/or investment).

To judge from our interview data – as well as other studies that we have carried out – the university-industry collaboration seems to work relatively well. There is certainly unexploited potential, which we have also exemplified in previous chapters, but there are as it seems other types of relationships that are in greater need to be strengthened. In particular, many interviewees call for closer collaboration between the healthcare system on one side and firms and universities on the other. We strongly recommend policy actors and support organisations to take measures that facilitate such interaction. We have already pointed at public innovation procurement as one possibility.

Another aspect that has come up in many interviews, with different types of persons, is the need and opportunity for increased collaboration between Chalmers and the University of Gothenburg. There are already many fruitful connections between researchers at the two universities. But we agree with interviewees that there is potential for – and strong need for – improvements, and that organisational and other barriers to effective collaboration should be eliminated as far as possible.

Firm-firm interaction is a third type of relationship that needs to be further stimulated. This is a part of the cluster-building process. Activities aiming to bring regional firms together and increase interaction are already carried out by support organisations, not least by GöteborgBIO (e.g., seminars, multilateral R&D projects, and joint participation in exhibitions and study trips). These are valuable activities that should continue and maybe be complemented by other measures.

Another means to build networks internationally, and achieve other positive effects, is to participate in EU-funded R&D projects. We believe that EU grants represent an untapped potential to attract supplementary resources and to strengthen collaboration and therefore need to be supported. This pertains both to firms and academic researchers.

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60 Cellartis can be given as an example of a firm that has been very successful in getting EU grants.
Scientific leadership
The region should try to attract more leading scientists from other parts of Sweden and from
abroad. This is of course important in order to maintain or increase the academic strength within the
different areas. In line with the high R&D intensity of the biomedical industry, and our whole-
approach to analyse the areas and their development potential, this is also expected to have positive
effects on innovation.

To attract more leading scientists to the region may require directed strategic measures taken by the
universities. This may include, for example, dedicated resources for recruitment.

A related issue is to secure succession of scientific leadership within each area of strength. We know
that in some areas, such as Vaccines for instance, several key individuals are to retire in a near
future. It is of utmost importance, if the areas are to remain strong, that the succession is appro-
priately handled.

Early-phase commercialisation
Like for R&D-based innovation in general (and within life science in particular) support of the early
phases of commercialisation is important for all five areas that we have analysed. For example,
verification grants such as those awarded by GöteborgBIO through Sahlgrenska Science Park are a
valuable tool in this respect. This is a type of activity that should continue and be further developed.
The same holds for incubation activities directed at biomedical projects and firms, including those
belonging to the analysed areas of strength.

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Appendices

Appendix A  List of interviews

1. Andersson, Bert, Medicine, Sahlgrenska Academy
2. Andersson, Marcus, Cochlear Bone Anchored Solutions
3. Belfrage, Bengt, GöteborgBIO
4. Bengtsson, Roland, Surgical Science,
5. Bengtsson, Stefan, Chalmers (Vice President)
6. Bergfeldt, Lennart, Medicine, Sahlgrenska Academy
7. Berglundh, Tord, Odontology, Sahlgrenska Academy
8. Blennow, Kaj, Neuroscience and Physiology, Sahlgrenska Academy
9. Borén, Jan, Medicine/ CMR, Sahlgrenska Academy
10. Brogren, Ulf, Promimic
11. Brånemark, Rickard, Brånemark Integration, Integrum, and Sahlgrenska Academy
12. Carlsson, Arvid, A. Carlsson Research
13. Dahlqvist, Patrik, Medfield Diagnostics
14. Edén, Staffan, Sahlgrenska Academy
15. Edgar, Boo, GöteborgBIO
16. Ekholm, Åsa, Simplexia
17. Elam, Mikael, Neuroscience and Physiology, Sahlgrenska Academy
18. Forsell-Aronsson, Eva, Radiation Physics, Sahlgrenska Academy
19. Elwing, Hans-Björne, Cell and Molecular Biology, University of Gothenburg
20. Enerbäck, Sven, Biomedicine/CMR, Sahlgrenska Academy
21. Engman, Fredrik, Neoss
22. Eriksson, Elias, Neuroscience and Physiology, Sahlgrenska Academy
23. Fäldt, Jenny, Nobel Biocare
25. Gisselfält, Katrin, Artimplant
26. Granström, Gösta, Ear-Nose-and-Throat Clinic, Sahlgrenska University Hospital
27. Grip, Lars, Cardiology, Sahlgrenska University Hospital
28. Gustafsson, Tomas, Micropos Medical
29. Göthberg, Andreas, BRG
30. Hammar, Patrik, Sahlgrenska Science Park
31. Hedman, Christer, BRG
32. Hellqvist Greberg, Marika, VGR
33. Hillbratt, Martin, Cochlear Bone Anchored Solutions
34. Hiort, Catharina, Chalmers
35. Holmberg, Björn, Neuroscience and Physiology, Sahlgrenska Academy
36. Holmes, Magda Alice, NidaCon International
37. Holmgren, Jan, Biomedicine, Sahlgrenska Academy
38. Hult, Johan, Multid
39. Håkansson, Bo, P&B Research and Chalmers
40. Idström, Peter, Vitrolife
41. Jacobsson, Magnus, Astra Tech,
42. Jamal El-Mosleh, Immunicum
43. Jeppsson, Anders, Medicine, Sahlgrenska Academy
44. Jern, Sverker, Medicine, Sahlgrenska Academy
45. Kuhn, Georg, CBR, Sahlgrenska Academy
46. Karason, Kristjan, Cardiology, Sahlgrenska University Hospital
47. Larkö, Olle, Sahlgrenska Academy (Dean)
48. Lausmaa, Jukka and Lyvén, Benny, SP
49. Lenning, Anders, Bellman & Symfon
50. Liljeqvist, Jan-Åke, Biomedicine, Sahlgrenska Academy
51. Lindahl, Anders, Biomedicine, Sahlgrenska Academy and CellMatrix
52. Lindecrantz, Kaj, University of Borås
53. Lissner, Lauren, Medicine, Sahlgrenska Academy
54. Lundqvist, Elisabet, Mölnlycke Health Care
55. Lundstedt, Johanna, Syspiro Diagnostics
56. Lycke, Nils, MIVAC, Sahlgrenska Academy
57. Lönnroth, Peter, VGR
58. Nielsen, Jens, Systems Biology, Chalmers
59. Nilsson, Karl Richard, Arterion
60. Nilsson, Michael, Sahlgrenska University Hospital (Director of Research, Development and Education)
61. NN, Auremune
62. NN, Qualisys
63. Norrman, Bo, Innovationsbron Väst and VGR
64. Nydén, Magnus, SuMo, Chalmers
65. Persson, Mikael, Biomedical Engineering/Chalmers and MedTech West
66. Petersson, Anders, Ostell
67. Rosengren, Annika, Medicine, Sahlgrenska Academy
68. Rydmark, Martin, Biomedicine, Sahlgrenska Academy
69. Sandström, Anna, Vinnova
70. Sartipy, Peter, Cellartis
71. Sjöblom-Hallen, Anna, MIVAC Development
72. Sjöquist, Per-Ove, AstraZeneca
73. Skarin, Morgan, Traccine Pharmaceuticals
74. Skoog, Ingmar, Neuroscience and Physiology, Sahlgrenska Academy
75. Smith, Jan, Abigo
76. Sonesson, Anders, Aidera
77. Sonesson, Clas, NeuroSearch
78. Stading, Mats, SIK
79. Stenlöf, Kaj, Gothia Forum
80. Strandwitz, Björn, Biopolymer Products
81. Svensson, Peter, Q-Sense
82. Swedberg, Karl, Medicine, Sahlgrenska Academy
83. Thomsen, Peter, Clinical Sciences, Sahlgrenska Academy
84. Westerkull, Patrik, Oticon Medical
**Appendix B  List of granting organisations**

The following is a list of the granting organisations which have financed the regional academic research during the period analysed.

<table>
<thead>
<tr>
<th>Granting organisation</th>
<th>Abbreviation</th>
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<td>Assar Gabrielson’s Research Foundation</td>
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<td>Avtal om läkarutbildning och forskning (ALF)</td>
<td>ALF</td>
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<td>Barncancerfonden</td>
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<td>Gates Found.</td>
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<td>Human Frontier of Science Program</td>
<td>HFSP</td>
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<td>Industry</td>
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<td>Inga-Britt &amp; Arne Lundberg’s Research foundation</td>
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<td>Jubileumsklinikens Forskningsfond</td>
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<td>Petrus &amp; Augusta Hedlund’s Foundation</td>
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<td>The Knut and Alice Wallenberg Foundation</td>
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Appendix C  List of research units

Biomaterials and Cell Therapy

At the University of Gothenburg/Sahlgrenska Academy:

- Department of biomaterials
- Institute of odontology
- Department of cell and molecular biology
- Department of orthopaedics
- BIOMATCELL
- Research group of Sven Enerbäck
- Research group of Anders Lindahl

At Chalmers:

- Biosynthetic Blood Vessels, BBV (together with University of Gothenburg)
- Division of biological physics
- Division of biomedical engineering
- SuMo

Research institutes:

- SP
- SIK

Vaccines

At the University of Gothenburg/Sahlgrenska Academy:

- MIVAC (Mucosal Immunobiology and VACcine) Centre

Medical Signal Processing and Visualisation

At the University of Gothenburg/Sahlgrenska Academy:

- Department of clinical neuroscience
- Department of radiation physics
- Mednet

At Chalmers:

- Division of biomedical engineering

At University of Borås

- Department of medical engineering
Neurological Diseases

At the University of Gothenburg/Sahlgrenska Academy:

- Centre for Brain Repair and Rehabilitation (CBR)
- Research group of Ingmar Skoog
- Research group of Elias Eriksson
- Research group of Maria Carlsson
- Research group of Kaj Blennow
- Research group of Bo Söderpalm

Cardiovascular and Metabolic Diseases

At the University of Gothenburg/Sahlgrenska Academy:

- Sahlgrenska Centre for Cardiovascular and Metabolic Research (CMR)
- Research group of Annika Rosengren (within the Institute of Medicine, Department of Emergency and Cardiovascular Medicine)
- Research group of Karl Swedberg (within the Institute of Medicine, Department of Emergency and Cardiovascular Medicine)
- Research group of Sverker Jern (within the Institute of Medicine, Department of Molecular and Clinical Medicine)
- Research group of Lennart Bergfeldt (within the Institute of Medicine, Department of Molecular and Clinical Medicine)
- Research group of Anders Jeppsson (within the Institute of Medicine, Department of Molecular and Clinical Medicine)
- Research group of Bert Andersson (within the Institute of Medicine, Department of Molecular and Clinical Medicine)
- Research group of Lauren Lissner (within the Institute of Medicine, Department of Public Health Epidemiology)

At Sahlgrenska University Hospital:

- Research group of Lars Grip (Department of cardiology)

At Chalmers:

- Research area Systems Biology
Appendix D  Other possible regional areas of strength

As indicated by the permission to carry out national healthcare Region Västra Götaland (mainly through Sahlgrenska University Hospital) has particular strength in the field of organ transplantation. Besides heart, liver and lung, the hospital’s Transplantation Centre has high competence also regarding other organs such as kidney, intestine and cervix. There is clinical research linked to these healthcare activities. Organ transplantation in general is thus regarded as an area of strength for the hospital and its management intends to support further development of this research by allocating money for strategic recruitments of scientists. The goal is to create an internationally strong research team.

One reason for not including organ transplantation as an area of strength covered by the present study is that there is presently little industrial activity in the region. But there is at least one firm involved and that is Vitrolife, where transplantation is one of three product areas. This means that organ transplantation should at least be regarded as a potential area of strength also from an innovation point of view. We therefore suggest that possible further mapping activities include organ transplantation.

Our interviews with representatives of the university hospital show that there are other areas where the region has clinical strength and which could also, in combination with supporting research activities, provide opportunities for innovation and industrial development. One particularly important specialty is children’s healthcare. The Queen Silvia Children’s Hospital, which is part of Sahlgrenska University Hospital and has some 1,900 employees, is one of Europe’s largest children’s hospitals, and it provides service in every major field of pediatric care. It also carries out clinical research in many areas such as neonatology habilitation and cardiac surgery to give some examples.

Plastic surgery, psychiatry, rheumatology, cancer, and care science are other examples of healthcare specialties where the region is regarded to have clinical strength.

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61 2009 sales amounted to SEK 40 million (out of MSEK 276 in total for the company).